A HEYWOOD PUBLICATION

British Chemical Engineering

THE JOURNAL DEVOTED TO THE TECHNIQUES OF CHEMICAL ENGINEERING APPLIED TO INDUSTRY

FEBRUARY 1959
Vol. 4 No. 2

Editor:
J. O. S. MACDONALD, B.Sc., A.R.I.C., A.M.I.Chem.E.

Associate Editor:
I. BERKOVITCH, Ph.D., F.R.I.C., A.M.I.Chem.E.

Assistant Editors:
WILLIAM D. CLIFFORD,
G. DILLEY, F.P.S.

A view of the new hydrogen peroxide plant at the Laporte Baronet Works, Warrington.

BRITISH CHEMICAL ENGINEERING is published monthly by HEYWOOD & CO. LTD., Drury House, Russell Street, Drury Lane, London, W.C.2 (Tel.: TEMple 3422), on the 20th of the preceding month. Annual subscription £1 10s. 0d. U.K., £2 sterling overseas for 12 issues post free ($6 U.S.A. and Canada) or by standing order through newsagents at 2s. 6d. a copy net. BRANCH OFFICE: Royal Buildings, 2 Mosley Street, Manchester, 2. Tel.: Central 9935 © Heywood & Co Ltd., 1958. Must not be reproduced without written permission.

MAIN ARTICLES

Ironmaking Without Blast Furnaces—A Review *by J. McKelvie, B.Sc.* 70

Production de fer sans hauts-fourneaux: Une revue
Eisenerzeugung ohne Hochöfen: Umschau
Изготовление железа без доменных печей: Обзор

A Radioactive Method of Measuring Low Water-flow Rates
by J. F. Cameron, B.Sc., P. F. Berry, B.Sc., and F. Taylor, A.M.I.Mech.E. 76

Une méthode radioactive pour la mesure des vitesses basses de l'écoulement d'eau
Eine radioaktive Methode zur Messung von niedrigen Wasserströmungsgeschwindigkeiten
Радиоактивный метод измерения низких скоростей потоков воды

Heat Transfer to Boiling Binary Liquid Mixtures—Part 2 *by S. J. D. van Stralen* 78

La transmission de chaleur aux mélanges liquides binaires bouillants—2e partie
Die Wärmeübertragung an siedende binäre flüssige Gemische—2 Teil
Теплопередача бинарным жидким кипящим смесям—Часть 2.

The Wetted-wall Column as an Evaporative Crystalliser *by J. L. Chandler, B.Sc. (Eng.), A.M.I.Chem.E* 83

Le tube à parois à coulement comme appareil de cristallisation par évaporation
Das Dünnschichtrohr als Verdampfungskristallisierapparat
Безнасадочная колонка в качестве испаряющего кристаллизатора.

Cost Control in Chemical Plant 92

Le contrôle des frais dans des fabriques chimiques
Kostenkontrolle in Chemikalienfabriken
Контроль над издержками производства на химических заводах.

OTHER FEATURES

Leader: Barriers to Progress 69
Ammonia Absorption in a Packed Tower 74
A New Process for Carbon Tetrachloride 75
Control of Air Condition in the Fog Region, *by R. H. Purdie, M.Sc., A.R.C.S., A.R.I.C.* 87
The World's Largest Hydrogen Peroxide Plant 88
American Letter: Growing List of Unit Operations 91
Steelmaking Reviewed, *by A. Noel Whiting, A.I.M.* 98
Fawley's £10 million Petrochemicals Plant 99
New Oil From Shale Process 100
Helium Separation by Diffusion 101
Nomogram: Determination of the Grashof Number 102

REGULAR FEATURES

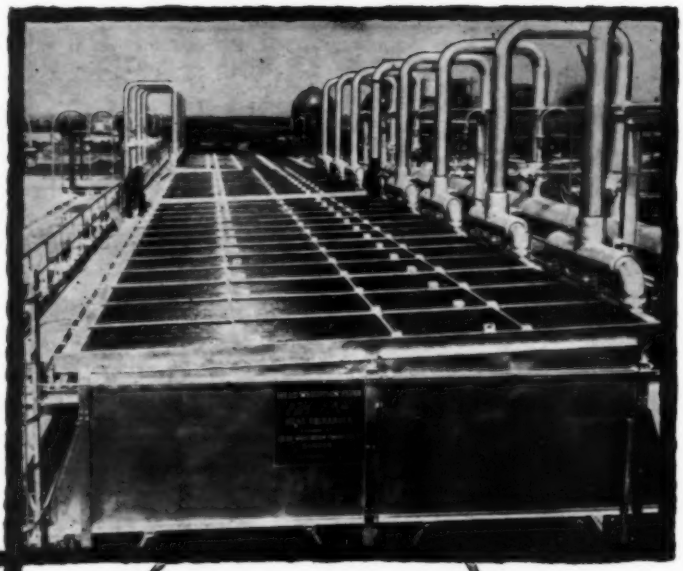
Digest 63
Process Engineer's Notebook 104
World of Chemicals 106
Book Reviews 108
Plant Equipment News ... 110
Month's News in Brief 120

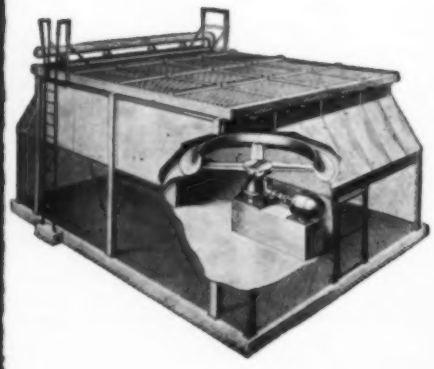
BCE 4662 for further information

BRITAIN'S LARGEST AIR-COOLED HEAT EXCHANGER

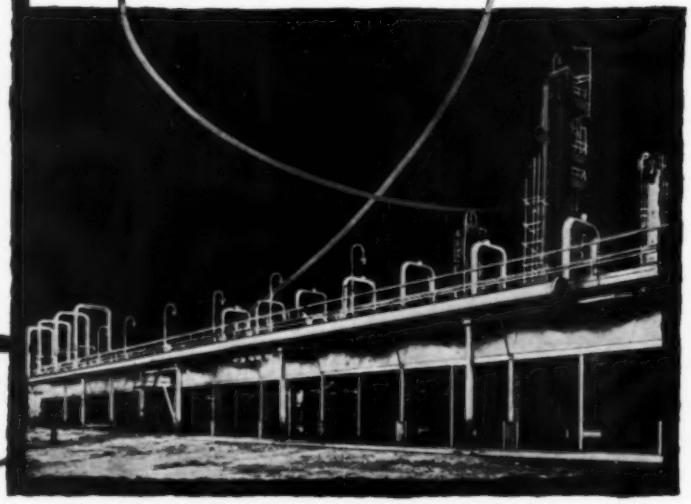
MANUFACTURED BY HEAD WRIGHTSON PROCESSES LTD

It is a *FIN-FAN* installation at Fawley Refinery, and cools steam and hydrocarbon vapour with a heat load of 173 x 10^6 B.T.U.'s per hour at a dry bulb temperature of 90°F. *FIN-FAN* is a forced-draught cooler of simple and robust construction, uses adjustable pitch propeller-type fans and is powered by steam turbines, electric motors, gas or diesel engines, etc. Many are in use on a variety of heat dissipation duties, from vacuum to pressures of 5000 p.s.i., temperatures to 1500°F. Temperature control and economic operation is guaranteed.





For further details write for brochures H.W.P. 5602 & H.W.P. 5701 or telephone our Technical Sales Division, CLErkenwell 1299



HEAD WRIGHTSON PROCESSES LTD

TEESDALE HOUSE 16/26 BALTIC STREET LONDON EC1

Offices at: P.O. Box 1595 **SYDNEY** P.O. Box 1034 **JOHANNESBURG** P.O. Box 2608 **CALCUTTA** and P.O. Box 706 **HAMBURG**

Associates in the U.S.A. The Fluor Products Company · Los Angeles 22 · New York · Chicago · Tulsa, etc.

F.2287

DIGEST OF INDUSTRIAL AND TECHNICAL DEVELOPMENTS

Economic Developments in Europe

BY the middle of 1958, the levelling-off of industrial production had spread to the great majority of western European countries and, in some instances, there was even a downturn. Industrial expansion had come to a halt earliest in the United Kingdom and in Denmark—which were the first countries to adopt restrictive policies in 1954/55 to restore balance-of-payments equilibrium. Belgium followed in the second half of 1956, then Finland, Netherlands, Sweden and Norway.

In western Germany output levelled off during the first three quarters of 1957, but a rise at the end of that year brought it to a higher level in 1958. In Italy, Austria and France, industrial expansion continued longest, although at a declining rate; and industrial output in 1958 has so far still exceeded the corresponding 1957 level. This sorry record is carefully set out in the latest *Economic Bulletin for Europe* (Vol. 10 No. 3, 1958.)* It serves to put in perspective the earlier OEEC survey of the chemical industry in Europe to which we referred in December, 1958 (p. 647). Although this earlier work is quoted, the ECE report appears to be a separate study. The authors agree that the growth of chemical production has in general slowed down only moderately. Among the major chemical producers, the expansion of production came to a standstill only in the United Kingdom, partly under the impact of declining foreign demand. Elsewhere the general stabilisation of industrial production has had only minor repercussions on the chemical industry owing, especially, to the continuous development of petro-chemicals and plastic materials. It is considered that the lower level of intra-European trade in chemicals may be, in part, the consequence not so much of reduced consumption but of the still rapidly increasing productive capacity in various countries.

And the general prospects? "The recent behaviour of the major sectors of demand does not warrant any expectation of a general and early speeding up of economic activity in western Europe, but neither does it point to a general contraction."

Meanwhile, despite great ideological battles on types of investment criteria, chemical and general industrial output in the East European countries continued to rise. Among chemical products nitrogenous and phosphate fertilizers in the Soviet Union at 9,200,000 tons were 7% up in 1958 on the output for the corresponding period of 1957 while the increase for all industry is quoted as 10%.

* Published by the United Nations Economic Commission for Europe.

How Much is Spent on Research?

IT is estimated* that in 1955, private manufacturing industry of Great Britain employed the equivalent of 109,500 full-time workers on scientific research and technical development at a total cost of £183 million. This represented 2.8% of manufacturing industry's contribution to the gross national product. Nearly 44% of the total expenditure on research and development was accounted for by that of the aircraft industry. This very large expenditure is believed to have been financed mainly by Government defence contracts and not out of the private resources of the aircraft companies.

Metal manufacturing and the engineering industries, including vehicles and aircraft, together accounted for 77% of the expenditure and the chemical industry (including mineral oil refining) for 13%. All other industries taken together contributed only £17 million or 10%. In addition, research carried out elsewhere—at Government establishments, universities and so on—brought the overall total up to £300 million. Distribution of manpower was also analysed. Engineers predominate in the metal-using industries but the chemical industries have a ratio of 84 scientists to 16 engineers. Some attention might be paid to the ratio of qualified to other staff which is 1:3 for all manufacturing industries but 1:1¼ for chemicals. Is it possible that we are wasting the time of qualified men due to having insufficient numbers of supporting staff?

The report is carefully produced with copies of the questionnaires and the definitions employed but a coy feature is the deletion of earlier estimates of distribution of manpower between civil and defence research. These estimates which appeared in the first duplicated version of the report† were accompanied by salutary hints on our relative profligacy of expenditure on defence projects compared with American practice. This valuable piece of self-criticism has been excised in the version offered to the general public. Even without this, the report is well worth reading. But why the delay in publication?

* Estimates of Resources Devoted to Scientific and Engineering Research and Development in British Manufacturing Industry, 1955. H.M.S.O. 3s. 1958.

† Presented to the British Association 1956.

Foaming at the Still

RESULTS of an investigation into the formation of foam in the highly active liquor evaporators at Windscale are not going to be direct value outside the field of atomic energy. Yet other workers faced with obstinate foaming may find it useful to read the report by N. R. GEARY* for an account of the method of attack. In the first place, attempts were made to operate a laboratory-scale, vapour-strip evaporator in such a manner as to provoke foaming. The rate of evaporation, rate of feed, concentration ratio and the concentrations in the feed of silica, graphite, free butex and butex impurities were varied. On occasions considerable quantities of foam were formed, but attempts to reproduce these results at will failed completely. It was, therefore, decided to divide the approach into two lines: to consider first the physico-chemical factors which affect the tendency of a solution to foam, and then, if necessary, to examine the chemical engineering aspects of evaporating a solution with a maximum tendency to foam.

Under standardised conditions nitrogen was passed through the test liquor and the foam level noted. A factorial experiment was designed involving six factors each at two levels, a total of 64 determinations. An index of foaming was adopted and a regression equation derived giving this

index in terms of the variables nitric acid, butex, silica, uranium, impurities and age. For those interested in results as well as method we would note that the major cause of foaming was found to be the product of the reaction between nitric acid in the still liquor and butex which had passed through an inefficient stripping column. Ageing produced a marked reduction in the foaming properties of a solution containing butex but did not entirely prevent foam formation. It was expected that the foaming would disappear when a more stable and efficient steam stripping column came into use for removing butex.

* Report No. R & D B (W) T.N. 163, Research and Development Branch, Windscale.

Residence-Time in Continuous Flow Equipment

TRACERS can be used to provide information on the passage of material through continuous flow process equipment. In a recent talk to the Scottish Group of the Institution of Chemical Engineers, PROF. P. V. DANCKWERTS pointed out that methods for determining whether the flow was piston-like or completely-mixed were already well-known. But, in addition, it is possible to find both the content and flow-rate of material by injecting a "pulse" of tracer at the inlet. This method can be used to find the volume of inaccessible vessels, or the hold up of one phase in a vessel containing two phases; it has been used to discover the degree of silting of an underground pipe.

Flow inside vesssels can be explored by injecting tracer at the inlet and taking samples from the interior or by injecting at points in the interior and sampling at the outlet. PROF. DANCKWERTS went on to discuss both these methods and further ones used for investigating the rate of replacement and flow-pattern of the air in ventilated spaces or furnaces by dispersing tracer uniformly through the space or injecting it at a number of internal points. Another variant of this approach might be used for determining the ultimate distribution of effluent discharged into the sea by continuous or batchwise discharge of tracer.

Standard Yard and Pound for Science and Technology

WHO nibbled at the Imperial standard pound? The truth is more pedestrian than this question suggests. The Directors of standards laboratories in the U.K., U.S.A. and some Commonwealth countries have agreed to adopt an international yard equal to 0.9144 metre and an international pound equal to 0.453 592 37 kilogramme. Unless otherwise required, all non-metric calibrations carried out by these laboratories for science and technology on and after July 1st, 1959, will be made in terms of the international units as defined above or their multiples or submultiples. It was in this announcement that the fell truth was revealed. Our pound (avoirdupois), has diminished by about 7 parts in 10 millions since 1846. It is believed at N.P.L. that this is essentially a loss caused by handling. In earlier years standards were not maintained with the same degree of care as now. The rate of loss has tended to diminish and the pound is now thought to be constant. Comparison with its currency namesake would be superfluous.

There were formerly slight differences in the standard yard and the standard pound in the U.K., Canada and the U.S.A. These have been resolved by the agreement. The new units will have no statutory force in this country but it is expected that the adoption of the international values of the yard and the pound will be of particular benefit to all those concerned with accurate measurements of length and mass for scientific and technological purposes in the British Commonwealth and the United States. We understand that it has been welcomed by the Scientific Instrument Manufacturers' Association.

Standards for Metals

A GROUP of newly published British Standards are of special interest to chemical engineers. As part of a comprehensive scheme of codes for pressure vessels for use in chemical and allied industries, British Standards 1501-1506 have been prepared covering carbon and alloy steels for plates, bars and sections, forgings, castings and bars for bolting material. A helpful feature of the composite publication is its indication of the nearest equivalent American steel in either the A.S.T.M. or the A.I.S.I. series. In view of the need for special requirements for steels operating at low temperatures, a companion to this revision has been issued as B.S. 1510.

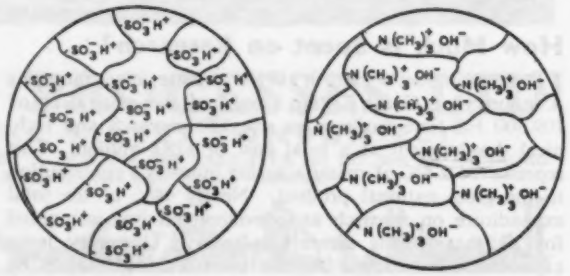
Acid resisting silicon iron pipes and pipe fittings are treated in B.S. 1333 which deals with cone ended, spigot and socket, and plain ended types of 1 to 12 in. nominal bore. The sockets are intended to accept the plain spigots of chemical stoneware of the same nominal diameter. At the same time a revision of B.S. 1633 (Steel for Land Boilers, Receivers and other Pressure Vessels) has been issued and, for welded austenitic stainless steel tubes, the new B.S. 3014. The latter specifies tubes for mechanical, structural and engineering purposes and includes metric equivalents. Prices of the relevant British Standards are: B.S. 1501-1506: 1958 25s.; B.S. 1510: 1958 4s. 6d.; B.S. 1333: 1958 6s.; B.S. 1633: 1958 6s.; and B.S. 3014: 1958 4s. 6d.

Standards of Safety

THERE are 16 British Standards covering a wide range of of safety equipment—helmets, boots, goggles and eye-protectors, gloves and respirators—and many such products are sold with the maker's assurance that they comply with the relevant standard. An article in *B.S.I. News* (November, 1958, p. 6) "turns the spotlight on industrial safety equipment" magisterially administering pats and kicks to manufacturers according to whether or not they tread the B.S. way. All of the Standards are dated within the last twelve years and nine of them have been drawn up or revised in 1954 or later. They are all relevant to large-scale chemical production and could usefully be studied by engineers with safety problems.

Ion-exchange Membranes

ACCORDING to a recent estimate, electrodialysis is the cheapest process for producing potable water of 500 ppm dissolved solids from brackish waters containing 2000-6000 ppm. Below 2000 ppm solids, ion-exchange processes become competitive and above 10,000 ppm multiple effect and



vapour compression distillation become progressively more attractive as a means of producing potable water. Source of these figures is a useful review of the general subject of ion-exchange membranes and their applications by H. T. HOOKWAY (*J.R.I.C.* 1958, Vol. 82, p. 763) The membranes are essentially water-swollen polyelectrolyte gels containing ionic groups fixed to the gel matrix. A schematic representation of a strongly acidic and a strongly basic resin bead is shown on the previous page.

It is these types which are of the most general interest. Other resins may contain weakly basic or weakly acidic groups, or chelating groups. Depending on whether the swollen gel contains acidic or basic groups, so it will exchange cations or anions with an ambient electrolyte solution. Provided there is a reasonably high concentration of ionic groups present, such membranes are good conductors of electricity. They function by virtue of the Gibbs-Donnan membrane equilibrium; a high concentration of fixed ionic groups in the membrane excludes diffusible ions of the same charge.

DR. HOOKWAY has kindly drawn our attention to the fact that there have been further developments since he prepared this survey notably based on co-operative research at T.N.O. laboratories in Holland jointly sponsored by the U.K., Holland, France and Australia. There is also work in progress at the Low Temperature Research Station, Cambridge where DR. PARTRIDGE is working on multi-compartment types of cell. These are intended eventually for commercial applications in the food industries, such as removing electrolytes from glycerol and ionic materials from sugar beet juices. Finally Permutit Ltd. and Ionics have recently made an agreement to market in the Commonwealth, electrodialysis units based on research work by Ionics.

Automatic Weighing of Vehicles

AS part of their work on examining the loads on our public highways, the Road Research Laboratory has developed an automatic wheel weigher. At present this is connected to circuits which provide counts of the numbers of vehicles with wheel loads up to 2000 lb., 4000 lb., and so on, at 2000 lb. intervals up to 20,000 lb. We asked MR. A. C. WHIFFIN, Head of Special Problems Section, whether the device could be adjusted to become an automatic factory weighbridge. The present platform, supported on four columns carrying resistance strain gauges, extends 6 ft across the width of the road and 2 ft along it. The electrical signal resulting from the passage of a vehicle across the platform is fed to a mirror galvanometer, arranged so that the light sweeps across 10 transistor photocells connected with electromagnetic counters. MR. WHIFFIN made it clear that a considerable amount of development work would be required to modify the equipment to record the weights of vehicles entering and leaving a factory. The platform dimensions would have to be increased, the pillar system carrying the strain gauges would have to be redesigned, and the vehicles would have to travel across the weighbridge platform at a fairly slow speed to avoid setting the platform into vibration. If the vehicles were all of one type so that their empty and full weights fell within two reasonably narrow bands, the zero of the equipment could be offset to correspond with the mean empty weight (or full weight). The sensitivity could be adjusted so that each photocell step represented, say, 100 lb. and the counters would then record the weights in 100 lb. steps around the mean. Obviously, two sets of counters would be required, one for incoming empty vehicles and the other for outgoing full vehicles. The differences between the two sets of readings could be analysed quite simply and would indicate the amount of material taken out of the factory.

Challenge to Engineering Mathematicians

WE recently received a query which sounds as though it should provoke engineers with a mathematical bent. A reader has asked if we can recommend a method for calculating the time required to exhaust the contents of a gas container, initially under superatmospheric pressure, to atmospheric pressure through a long pipe-line and packed tower in series. This problem arose in connection with using the packed tower as a noise silencer when regenerators were switched in an air separation plant. Our enquirer solved the problem by making simplifying assumptions and numerically integrating, but we wonder if anyone has worked out an analytical (mathematical) solution that can be solved directly.

Size Classification Can Change Composition

IN some instances size classification also results in a chemical or other type of separation. The principle has been used in petrographic separations of coal and a fresh example has now been provided by the results of air-classifying flour. C. R. JONES and his colleagues of the Research Association of British Flour Millers have reported marked differences in composition of different sizes in the sub-sieve range. Below 17 microns, the fraction is of high protein content and contains fragments of interstitial endosperm protein and small starch granules. Between 17 and 35 microns there are mainly large starch granules of low protein content, while fragments of endosperm cells characterise the portion coarser than 35 microns. The yields and protein contents of the fractions vary with different wheats and grinding conditions. In general, the fines may be used for raising the protein content of flours deficient in protein to a level suitable for bread-making. The amount of fines required depends on the protein content and whether it came from a hard or soft wheat, the hard wheat fraction having better bread making qualities. Nevertheless, there are other complications. Diastatically active agents and finely divided discolouring matter become concentrated in the finest fraction and the former greatly affect the bread-making value. In juggling with these factors it may be necessary to carry out pre-grinding of the flour.

Separations were carried out by means of a Bahco elutriator on the laboratory-bench scale, and a Mikroplex air classifier in continuous operation on the larger scale. Details are given in a paper which is to appear shortly in the first number of *Biochemical and Microbiological Technology and Engineering*.

Refractories for Glass Tank Furnaces

LESS than 5% of the refractories produced in this country are consumed by the glass industry. The major user of refractories, the steel industry, takes about 65% of the output. These proportions, plus a certain basic similarity in process, have meant that the glassmaker has had a wide choice between the many varieties of silica, fireclay, high-alumina and basic refractories developed to withstand the generally more arduous conditions in steel-melting furnaces. Thus, the provision of refractories for roof, breastwalls, ports, regenerator chambers and fillings has simply been a question of choosing between the numerous qualities available subject to the cost. Refractories which are to be in contact with glass are however special to the glass industry and a valuable service has been performed by the Refractories Committee

of the Society of Glass Technology in publishing a review of this subject.* It opens by considering the properties of silica refractories and those based on bonded alumina-silica, then examines the possibilities of using basic materials such as magnesite or dolomite and finally the zircon refractories. Practical conclusions have been drawn on the choice of materials for the various parts of glass tank furnaces. Most attention is given to the regenerator checker where the widest divergencies in practice are found. Here the Committee appear to be leaning towards advocacy of the use of basic materials and of zircon bricks as their commercial production increases.

* *J. Soc. Glass. Tech.*, Vol. XLII, 1958, No. 209, p. 63P.

Processes Developed by the Institut Français du Pétrole

MOST secondary alcohols—aliphatic or cyclic, anhydrous or hydrated—can be converted into the corresponding ketones in *liquid* phase at temperatures as low as 300° F. by means of a new process announced by the Institut Francais du Pétrole (Rueil-Malmaison, France). Catalysts for the dehydrogenation are Raney nickel for aliphatic, and copper chromite for cyclic, alcohols. One factory has been built which uses this method, a second is being built and several more are being planned. We have recently seen reports on the ketone manufacturing process and also on others for making isoprene and oxidation products of tetralin. They all include cost estimates. Incidentally, the sketches of the projects for 5000 ton per year M.E.K. and acetone plants are unusually aesthetically pleasing.

The same section of I.F.P. have also announced development of processes for making adipic acid and cyclohexene, and for hydrodesulphurising crudes, petroleum products and residues. The institute is prepared to grant licences for the use of its processes, and has even set up a company to assist in putting them into operation if required.

This impressive list of achievements for a post-war creation results from only one of a wide range of activities which include education, documentation, studies in oil prospecting and work on motors.

Disposing of Trade Wastes

BECAUSE industrial wastes vary so widely the traditional methods of sewage treatment such as screening, sedimentation, biological purification and final clarification are only of limited efficiency in many cases; even where they are feasible, they usually require certain modifications. Generally, industrial waste cannot be dealt with satisfactorily by these methods only. They must either be replaced or supplemented by other methods. In a detailed examination of the whole field, PROF. F. MEINCK of the Institut für Wasser, Boden and Lufthygiene, advised that treatment should begin with a case history, continue with collection of data on compositions and amounts and lead up to preparing a flow diagram. In this it is also useful to incorporate water requirements. Pre-treatment of wastes will generally be necessary if these contain free acids, alkalies, toxic compounds, oil and/or grease, hazardous gases or sources of odour nuisances, pathogenic germs, coarse or bulky material, high concentrations of certain salts or if they have too high a temperature.

This is a valuable review, for a treatment in one industry may not be noticed in the literature of another where it may be helpful. Tabulation of treatment methods has been rounded off, in the most positive way, with guidance on reduction of waste flow by recirculation and on recovering utilisable substances. The paper was presented to the Public Works and Municipal Services Congress with others on water supply and waste treatment. A full report of the congress is due to be published this year by the organisers.

Performance of Low Pressure Gas Injectors.

IT has long been a part of the British *mystique* that test results on named products may not be published for risk of dire consequences. Consumer research organisations have successfully challenged this concept for domestic goods and the Gas Council seem equally bold in respect of gas fittings. Reports have been issued on a series of branded low pressure injectors for industrial gas burners to assist engineers in assessing the performance. Commercial injectors—consisting of an injector orifice, throat, air control and adaptor for attachment—have been tested in this way.

The injector is assembled and fitted to a bar burner having a very large area of flame ports. The injector is then fitted in turn with a series of injector orifices providing, at a constant gas inlet pressure of 2.5 in. w.g., a range of gas rates. At each gas rate flame ports are covered so that air : gas ratios of approximately 2.0, 2.5 and 3.0 are obtained with the air shutter fully open. From these results the flame port area required for these exact air : gas ratios with gas of specific gravity 0.47 is estimated and the air : gas ratio corrected for other specific gravities by means of the square-root relationship. It is considered that for low-pressure burner operation these air : gas ratios represent minimum aeration, keen aeration and over-aeration for gas with a calorific value of 500 B.t.u./ft³. The tests are carried out with the throat and without the throat in the injector, and with the burner hot in free air.

Results are then plotted, showing the performance with and without the throat. Injector orifice area is plotted against the flame port area and lines of air : gas ratios 2.0, 2.5 and 3.0 are shown. The graphs are clearly marked with the usable area and the unusable area for the injector and, for convenience in use, two tables are included summarising the limits of usability with and without the throat.

* Reports Nos. 683/58 to 695/58 of the Industrial Gas Development Committee.

Economics of Heat Pumps

WHAT is the optimum size of a heat pump for space-heating purposes? The high capital cost suggests that the plant must be made small enough to have a high load factor. In a recent paper* MR. P. E. MONTAGNON of the Chief Scientist's Division, Ministry of Power, has examined in detail the possibilities of domestic use in the London area. MR. MONTAGNON decided that, with certain reservations, it was possible to make an economic case in support of a small heat pump for domestic refrigeration and producing hot water in summer. For industrial drying and distillation, however, the reduction in fuel consumption appeared to be so large that it seemed worth considerable effort to explore them further by practical tests, which are indeed being carried out. In drying the clue is to use the moist vapour as a source of low grade heat for a heat pump whose hot side is providing the heat for the next cycle of drying. Without the use of the heat pump, fuel energy is thermodynamically wasted, since it reappears as useless latent heat at a comparatively low temperature in warm moist air. Distillation is thermodynamically similar but here of course use is already being made in many cases of vapour re-compression for salvaging the latent heat which would otherwise be carried away by the condenser coolant.

* *Journal of the Institution of Heating and Ventilating Engineers*, Vol. 26, 1958, p. 233.

British Chemical Engineering
A HEYWOOD PUBLICATION

Barriers to Progress

THE modern era is one of unprecedented speed of technological development with progress accelerating continually in an astonishing manner. In mathematical terms, this progress is of a kind where the second derivative of distance with respect to time is neither constant nor zero, but seems always to have a positive value of increasing magnitude. In an earlier era almost a century had to pass before the discovery of steam power led to the ultimate generation of mechanical energy from steam; in more recent times less than a tenth part of this period was needed for the discovery of the splitting of the atom to bring into being the greatest source of power known to man. The more recent creation of an artificial solar satellite, another testimony of man's growing mastery over the forces of Nature, is a topical and striking example of a feature typical of the modern era, the closeness in time between discovery and practical application. Although recent successes are a reminder that science knows no boundaries, this shortening time lag provokes the thought that the rate of application of fundamental discoveries is outpacing the output of the discoveries themselves. There are fears that the supply tank of new ideas is at a low level, and that the contents are steadily being depleted. Since science plays such a dominant role in the advance of civilisation, the grounds for such fears ought to be closely examined and hindrances to new discoveries exposed.

Here it is appropriate to consider one or two important problems which confront us. We are faced, for example, with a diminution of many important raw material resources; copper may be taken as an example to illustrate this point. In the eighteenth century ore containing less than 13% of copper was deemed too poor to be worth mining; at the turn of the nineteenth century ore with a 5% copper content was being mined; nowadays a high proportion—well over half—of 1% copper ore is considered worth processing. This trend is to be found with almost every important mineral, as well as with the fossil fuels. It is evident that abundant material will eventually have to be processed by methods so far unknown. Water for irrigation and industrial use will more and more have to be prepared by treatment of sea water, perhaps by distillation using cheap energy derived from nuclear fusion.

Not the least important factors in the progress of science and technology are the extent and speed of exchange of new ideas, observations and experiences between workers with similar interests. If these processes are haphazard and ill-organised, as many believe they are, then inevitably there will be a great deal of needless waste and duplication of effort, as well as much chasing of will-o'-the-wisps. Whether man can afford the luxury of such a situation, especially in face of the increasing difficulties of wresting from Nature her secrets, is open to serious question. This needs to be considered when the over-optimistic point to the volume of scientific publication—there are some 50,000 now in existence—as evidence of progress.

One of the problems which many investigators encounter is indeed this large volume of literature. It is virtually impossible for one man to read all the material in his particular field, let alone to venture extensively beyond it. Yet wide reading is gaining in importance, for often the most striking results are obtained in fields where several branches of science and technology overlap. Abstracting services go some way towards surmounting this problem, although it would seem that the tide of new work published in foreign languages advances too fast for present abstracting sources to keep abreast of it. This is becoming more serious with the rapid expansion of scientific research in countries for whom this is a comparatively new form of social activity. There is a real danger that the language barrier will keep many workers in prolonged ignorance of developments they should know about. The latest Russian achievements in rocketry may remind us that the scientific and technical literature appearing in the Russian language is expanding rapidly. Moreover, we can expect China to publish literature in increasing quantities, a great deal of which will, without doubt, appear in the Russian language as well as in Cantonese. It will be necessary to cope with an unprecedented flow of important work written in a language totally unknown to most scientists and engineers. The obvious solution of translations is an expensive one, and there are few translators who can produce useful translations in more than one or two specialised subjects.

The language barrier to science is a hindrance to its development and how it will be surmounted is difficult to forecast. The real solution may be a long-term educational one of two or three languages to be mastered by every intending scientist and engineer. If current educational curricula in this country are anything to go by, this solution must appear almost impracticable.

So far as research itself is concerned, the flow of knowledge may be hindered by the greater concentration upon what we might call directed research as compared with non-directed research. In the first would be included industrial, applied, technological, pure and development research and in the second would be found academic, pure and technological research. The former requires an economic solution to be found to a problem; if negative results are obtained the work may be regarded as a financial loss. It is this type of work that absorbs by far the greater proportion of scientific effort. The second does not demand an economic solution, nor do negative results matter. If a subject not productive of new knowledge is chosen, and found wanting, another choice can be made. Such work stands or falls on its merits as sound scientific work, whereas in directed scientific research the work may easily be of poorer scientific quality and yet yield high dividends to industry. But it is from the undirected research that the greatest discoveries will come. To fail to give adequate support to this kind of work is to gamble with progress and to run the risk of the intellectual storage tank becoming dry.

669.181.24

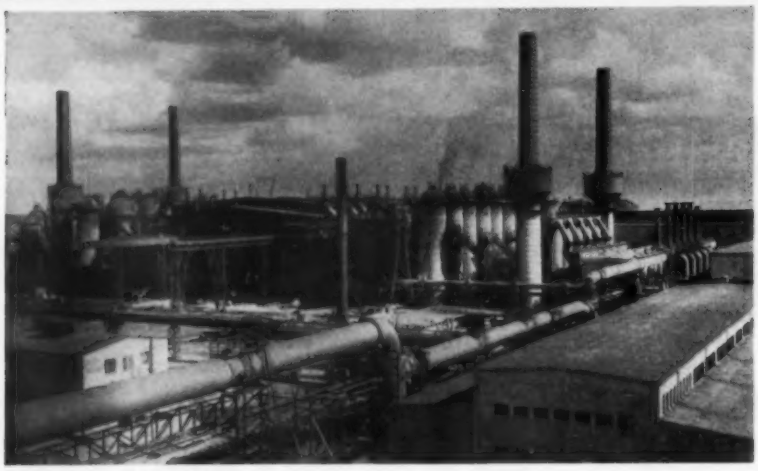


Fig. 1. Low-shaft furnace plant at Calbe, Eastern Germany, for the commercial production of pig iron.

IRONMAKING WITHOUT BLAST FURNACES

A REVIEW

by J. McKELVIE, B.Sc.

Although 99% of the world's current output of iron is made in blast furnaces, other methods of reducing iron ore, reviewed here, may transform the future of ironmaking

FOR many years iron has been reduced from its ores almost exclusively by the blast-furnace process. The great bulk of the pig iron thus produced is further transformed to steel, a minor proportion being used in the production of iron castings. The possibility of producing steel directly from iron ore, without passing through the pig iron or some other intermediate stage, is an attractive one in theory, but no such process has yet attained large-scale commercial success in spite of many attempts in this field.

In certain circumstances, however, it may be advantageous to use an alternative to the orthodox blast furnace for the primary ore reduction stage. Apart from iron ore, coke is the chief material required in ironmaking by the blast-furnace process. Since the height of the column of charge in a modern blast furnace may be up to 80 ft, the coke has to be of high mechanical strength in order to withstand crushing and thereby maintain an open stock column which will allow free upward passage of blast. The coke should also have a low ash content and as low a sulphur content as possible. The world's resources of coking coal are somewhat unevenly distributed and in certain regions an ironmaking process independent of coking coal, or requiring a reduced amount per ton of iron as compared with the blast furnace, might be economically sound.

The present article reviews such processes, dealing in the first place with those at present used commercially and, secondly, with some processes currently being developed. Electric smelting is excluded. It is now a well-established ironmaking method used where hydroelectric power is available as in Scandinavia and Northern Italy. The ironmaking processes used at present on an industrial scale are listed below with the approximate world annual tonnage produced by each.

Process	*Annual Tonnage* (1957)
Blast furnace	205,000,000
Electric smelting	1,500,000
Low-shaft furnace	300,000
Krupp-Renn	500,000
Basset	50,000
Sturzelberg	10,000
Sponge iron processes	200,000

Low-shaft Furnace

As the name implies, the low-shaft furnace[1] is essentially a blast furnace with the stack height drastically reduced. It has been developed to allow the use of a weaker coke and a smaller-sized charge than would be suitable for the orthodox blast furnace. It is also particularly suitable where the blast is oxygen-enriched, since the consequent reduction in gas volume per unit of iron made allows gas-solid heat transfer to be completed in a shorter height of shaft than would be required with a normal air blast. At the present time the only low-shaft installation producing significant quantities of commercial pig iron is at Calbe in East Germany.[2,3,4] After the war, the Eastern zone, which has few coking coal deposits, was cut off from supplies of Ruhr coke. The Calbe low-shaft furnaces were therefore built to produce pig iron using the native coal deposits which could give only an inferior grade of coke. There are now 10 low-shaft furnaces, all of rectangular design, at Calbe. The plant was completed in March, 1953. In general, the furnaces have a hearth breadth of 6 ft and a length of 20 ft, the height from tuyeres to stockline being 16 ft. Nos. 1 and 2 furnaces, the earliest built, are somewhat smaller. There are 14 tuyeres per furnace. The yearly production from the plant is between 200,000 and 250,000 tons of foundry iron. An interesting development at Calbe has been the use of coke made from lignite which resulted in a lower fuel consumption and increased iron production as compared with the gas coke previously used.

In Western Europe interest in the low-shaft furnace was aroused in 1950-51. An international committee consisting of seven countries—Austria, the Benelux countries,

Mr. McKelvie *studied metallurgy at the Royal Technical College, Glasgow, and is at present with the British Iron and Steel Research Association's Ironmaking Division.*

France, Greece, and Italy—together with the Battelle Memorial Institute of America, was established to undertake research on a low-shaft furnace to be built near Liége in Belgium.[5, 6, 7, 8] The idea was to utilise Minette ore fines and low-grade fuels which are unsuitable for blast-furnace working. The furnace was first blown in during May, 1953. It is of oval section, the hearth being about 10 ft by 4 ft and the height from tuyeres to stockline 16½ ft. There are ten tuyeres. Low-grade ores were used in the trials, the iron content running from 25-35%. In general, about 50-60% of the ore charged was sized 10 mm to 20 mm, the minus 10 mm fraction being 20-35%. The size grading of the coke was slightly larger than that of the ore. For many of the trials the oxygen content of the blast was enriched to 28% as against the 21% of atmospheric air. The pig iron production was between 35 and 40 tons a day.

A further interesting possibility is to use the low-shaft furnace to smelt a briquetted charge of fine ore and coal. The firms of Klöckner-Humboldt-Deutz and Demag have jointly formed a company to exploit this process. For this DHN process,[9] as it is known, ore and bituminous coal with some limestone as flux are finely crushed and well mixed. The mixture is then briquetted with tar as a bonding agent and the briquettes charged to a low-shaft furnace. This is blown with heated blast, as in normal practice, and the briquettes smelted to iron and slag. The gas coming off the furnace top, which contains the distillation products of coal, is treated to recover tar and other by-products. A fraction of the tar recovered is used again for briquetting. A small pilot plant of 10-15 tons a day capacity has been operated for some time.

Rotary Kiln Processes

Instead of using a vertical shaft for the reduction of iron ores, as in the blast furnace and low-shaft furnace, it is possible to use a rotary kiln which is the basic equipment employed in a number of ironmaking processes. The various rotary kiln methods have this in common: that a charge of ore and carbonaceous material plus suitable flux as required is fed to the kiln which is heated up to allow reduction to proceed. The processes differ among themselves, chiefly in the operating temperatures employed and the slag compositions used.

The best known of these processes is probably the Krupp-Renn.[10, 11] A long rotary kiln is employed which may be 100 m long by 4.2 m in diameter. The kiln is a steel shell, lined internally with suitable refractory bricks and inclined slightly to the horizontal. Fine ore and coke are charged at the higher end and the finished product discharged at the lower. A pulverised-coal burner at the discharge end of the kiln is used intermittently as required to maintain the correct temperature conditions. The temperature at the discharge end of the kiln is about 1300°C. As the solid charge progresses through the kiln, reduction of ore takes place and eventually a pasty slag is formed in which are dispersed small granules of metallic iron. On discharge from the kiln the mass of hot pasty slag, containing the iron granules in suspension, is cooled by water and then goes to a ball mill. This crushes down the slag, leaving the larger granules of iron which are recovered by screening at about 10 mm. The undersize passing through the screens, which consists of slag and fine particles of iron, is then separated magnetically into three fractions; a metallic fraction, an intermediate magnetic concentrate which is recycled to the kiln and tailings which are discarded. The Krupp-Renn process is particularly relevant for low-grade, highly siliceous ores. Whereas in the blast furnace the ratio CaO/SiO_2 may be 1.3 or so, in the Krupp-Renn process it is 0.1 to 0.3. A consequent disadvantage of this very acid working is the high sulphur content of the iron produced, which may be up to 1%. Because of this, the iron granules are often remelted in blast furnaces to eliminate the sulphur and provide hot metal at high furnace productivity and low metallurgical coke rate.

The Krupp-Renn process was developed in the period 1932-33 and a kiln was built at Essen. During the war a plant was constructed at Watenstedt in Germany to treat the low-grade ores of the Salzgitter deposit and in the war period kilns were also operating in Poland, Manchuria, Korea and Japan. After the war, however, the process declined and most of the kilns went out of operation, the Watenstedt plant being dismantled by the Allies. Then a few years ago it was decided to build a new Krupp-Renn plant of three kilns on the site of the old wartime plant at Watenstedt. This plant went into full production last year and has an annual capacity of 600,000 tons of ore, equivalent to about 200,000 tons of metallic iron. A plant of double this capacity is being constructed at Essen-Borbeck.

The Basset process,[12] also using a rotary kiln, works at higher temperatures than the Krupp-Renn process and the slag composition is made highly basic (CaO/SiO_2 ratio about 3.0) instead of siliceous. The process is worked to produce pig iron and a Portland cement clinker simultaneously and is continuous in operation, as is the Krupp-Renn. A plant has been using the process at Aalborg in Denmark since 1939, the annual capacity being about 50,000 tons.

The Sturzelberg process[13] takes its name from a town situated on the Rhine and is worked on a by-product of the sulphuric acid industry known as purple ore, which has too high a zinc and too high a sulphur content for normal blast-furnace operation. Like the Basset process, the Sturzelberg process uses a high lime slag but is a batch process. Pig iron of special quality is produced and also ZnO.

The idea of carrying out a low-temperature (*ca.* 1000°C) reduction in a rotary kiln to produce a sponge iron is

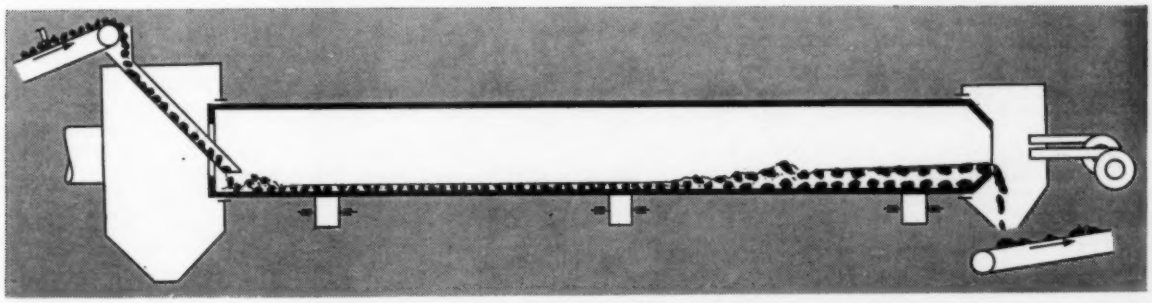


Fig. 2. Diagrammatic representation of charge flow through Krupp-Renn furnace.

quite an old one, but the process has not yet been exploited on a large scale. The United States Bureau of Mines has carried out extensive trials on different kilns and operating methods.[14] Tests have been carried out in a semi-scale furnace at the Domnarfvet Steelworks in Sweden.[15] The Anaconda Copper Co. produces sponge iron for precipitating copper by low-temperature rotary kiln reduction.[16]

A process which is attracting some interest at the moment is the R-N rotary-kiln process.[17] This has been developed by Republic Steel Corp. and National Lead Co. in America and it is understood that a pilot kiln is in operation at Birmingham, Alabama. The process essentially consists in charging a mixture of ore and coal to a rotary kiln and heating to a temperature not exceeding 1000°C so that no fusion of the charge takes place. It is claimed that by this method low sulphur and phosphorus contents are obtained in the metal. On discharge from the kiln, magnetic separation is carried out and the iron concentrate compacted for charging to steel furnaces.

Sponge Iron Processes

Sponge iron is the metallic product resulting when iron ores are reduced without melting. The simplest method of making it is to heat a mixture of ore and solid carbonaceous material in a suitable container. This is the basis of an early Chinese method of making iron, the Shansi process. A successful commercial process using the same principle is the Höganäs process,[18] taking its name from the town in South Sweden where the process is worked. Here a very pure iron concentrate (71.5% Fe) is charged centrally in cylindrical clay saggers and surrounded with a mixture of coke breeze and limestone. The saggers are fired in a ring kiln, the maximum temperature being 1150°C. The complete firing schedule, from charging to discharging of containers, takes about 11 days. The sponge iron produced by this process, containing 96-97% Fe, can be charged to open hearth or electric steel furnaces, but a large proportion of the output is now further concentrated magnetically and used in powder metallurgy.

A plant of generally similar design to the one at Höganäs is in operation at Riverton, New Jersey. Plants of tunnel kiln design are used to produce sponge iron, for use in steelmaking, at Monterrey, Mexico, and Oxelosund, Sweden.[19] Instead of employing solid carbonaceous material directly as reducing medium, gaseous reduction may be used. A sponge iron process based on gaseous reduction which is being increasingly used in Sweden is the Wiberg process, named after its inventor.[20, 21] The Wiberg process is now operated at five different plants in Sweden and the total tonnage produced is in excess of 100,000 tons per annum.

Fig. 3 illustrates plant layout and materials flow and consumption in the Wiberg process. An iron ore charge is fed to a vertical refractory-lined shaft about 60 ft high and hot reducing gas (900-1000°C) is passed upwards through the charge. The gas composition entering the foot of the reduction shaft is about 75% CO and 20% H_2, so chosen since with this composition the reduction of iron ore to metallic iron is slightly exothermic. The greater part of the gas is withdrawn from the shaft about two-thirds of the way up and goes to a coke-filled, electrically-heated carburettor which reheats the circulating gas and largely converts carbon dioxide and water formed during reduction of iron ore to carbon monoxide and hydrogen. Coke consumption is about 4 cwt and power consumption 1000 kWh a ton of sponge iron produced. Hydrogen has to be added in some form to keep the proper gas composition. Formerly this was done by adding water to the carburettor, but now oil or other suitable hydrocarbon is added.

During the early years of the Wiberg process, charcoal was used in the carburettor, but for economic reasons coke has subsequently been adopted. This gave rise to a sulphur problem, and a tower containing dolomite to act as a desulphurising agent was introduced in the gas circuit after the carburettor. After passage through the dolomite tower the gas enters again at the bottom of the reduction shaft. A portion of the gas passing up the reduction stack is not recirculated with the main stream but continues further, carrying out some more reduction. Then towards the top of the shaft excess air is admitted which burns the residual gas, the ore being heated by this process to about 1000°C.

The ore charge to the reduction shaft is now invariably in the form of pellets. At one particular Swedish works the ore as mined is a low-grade magnetite containing 24% Fe. This is finely ground and magnetically separated to produce a concentrate of 67-68% Fe. The concentrate is then charged to a rotating pelletising drum where a certain amount of water is added. On discharge from the drum, the pellet diameter may be 1 in. or so. The pellets are then fired in a shaft kiln to about 1300°C, a minimum amount of fuel being used to keep the atmosphere oxidising. After this firing treatment the pellets are

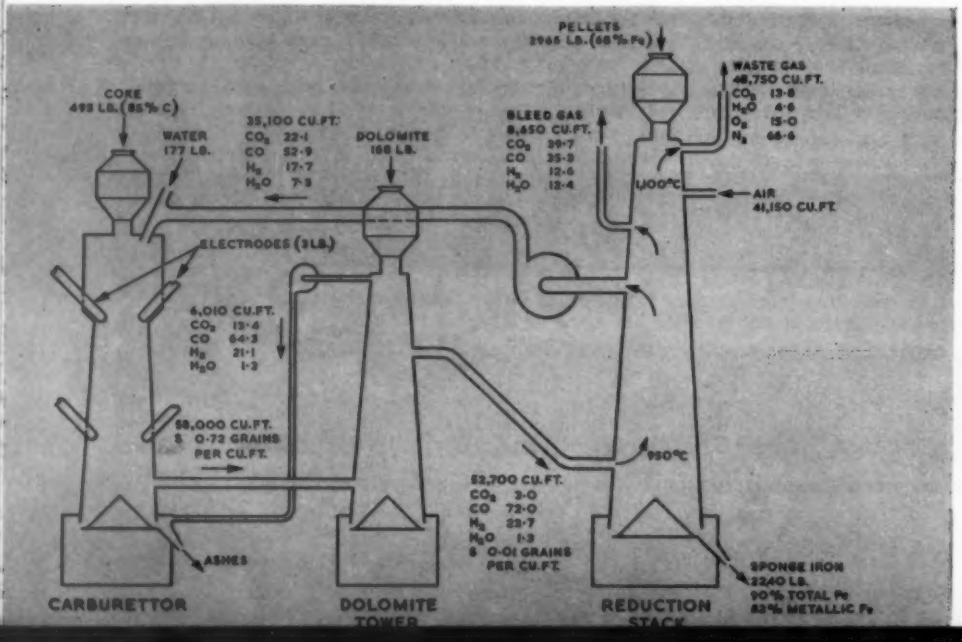


Fig. 3. Gas flow and materials consumption in Wiberg process. Figures are for usage or gas volume passed per ton of sponge iron produced.

quite hard and withstand handling. It may be mentioned that the use of pellets is not confined to the Wiberg process for they are an acceptable blast-furnace charge and pelletising of iron ores has become a very considerable industry in the United States. The reduced iron pellets are discharged periodically from the shaft and allowed to cool in air-tight containers to prevent reoxidation. When cool the sponge iron pellets are charged to open hearth or electric steel furnaces.

HyL Process

Another sponge-iron process is the recently developed HyL process (see Fig. 4). An existing plant is in operation at Monterrey, Mexico, and it employs a gas containing approximately 85% hydrogen and carbon monoxide obtained by re-forming natural gas. Hæmatite is reduced batchwise in fixed-bed reactors. The existing 200-ton-a-day plant uses an ore of from ¼ to 1½ in. in size. Natural gas requirements are about 21,000 scf a ton of reduced ore. The ore reduction takes place within a temperature range of 1600-1900°F. The sponge-iron product replaces pig iron or scrap metal in the electric melting furnace and yields a steel of exceptionally high quality, capable of being used for electric resistance welded pipe. A 500-ton-a-day plant using this process is to be erected by M. W. Kellogg, also at Monterrey, and it is expected that considerable economies will be effected in the new plant. This process, which can handle ores with a high percentage of fines and which are difficult to handle in the blast furnace, should prove very attractive to countries and companies where iron ore and natural gas are available together. The power consumption in the 500-ton-a-day plant has been estimated at 9.6 kW per ton of iron, the investment is $29 a ton of iron a year, and the natural-gas requirement is expected to fall to around 15,400 scf.

Fluidised Reduction

The processes previously considered all use coal or a coal product as the reducing agent. Another possibility is to use oil or natural gas as the primary material from which the reducing agent is obtained and in this field a number of variants are currently being developed in America. These schemes generally carry out the ore reduction under fluidising conditions.

Flow diagrams of the H-Iron process,[22] developed by Hydrocarbon Research Inc. and Bethlehem Steel Corp., have been published previously in *British Chemical Engineering*.[23] The process is a batch one as far as the ore is concerned. An ore batch, sized 20-325 mesh, after drying and preheating to about 500°C, is fed to the reducing vessel via a charge hopper. In the reducer the fine ore forms a fluidised bed with a hydrogen gas stream flowing upwards, the temperature of the incoming hydrogen being about 550°C and the pressure 400 psi. On passage through the reducer the gas is cooled and water formed from the reduction of ore condensed out, the hydrogen being recycled. After eight hours about 90% reduction of the iron ore may be obtained. The sponge iron produced is compressed to form small chips or larger briquettes for charging to steel furnaces. The method of producing make-up hydrogen is based on the partial oxidation of natural gas by oxygen, a reaction which may be represented, taking natural gas as mainly methane, $CH_4 + \frac{1}{2}O_2 \rightarrow 2H_2 + CO$. The gas produced in the first stage is then reacted with steam to convert CO to CO_2.

$$2H_2 + CO + H_2O \rightarrow 3H_2 + CO_2.$$

The CO_2 is scrubbed out by an ethanolamine tower.

The distinctive features of the H-Iron process are the use of virtually 100% pure hydrogen, the low reaction temperature (500-550°C) and the high pressure (400 psi) employed. The high pressure allows a greater mass of gas

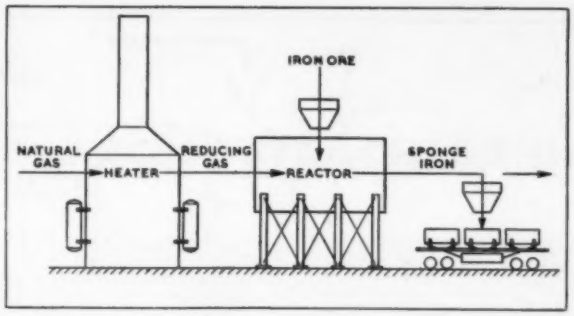


Fig. 4. HyL sponge iron process using natural gas or light hydrocarbons as developed by the Mexican company, Hojalata y Lamina S.A., with engineering assistance from Kelloggs of New York.

to be circulated per unit time for the same linear velocity through the bed. The low temperature is used to prevent fritting together of the particles which has been a major difficulty with similar schemes in the past.

The United States Steel Corp. is also developing a process of natural gas reduction and some pilot work has been carried out at the Corporation's South Chicago works. Here the reducing gas is a mixture of CO and H_2 produced by steam-methane reforming, $CH_4 + H_2O \rightarrow CO + 3H_2$. Powdered ore is first fed to a preheater where the sensible heat of gas from the reducer serves to raise the temperature to 370°C, and then to an ore heater where the temperature is raised to 930°C. The heated ore is then passed to the reducing vessel which is a fluidised-bed reactor, the working gas pressure being 60 psi. After reduction, the iron powder is cooled in an air-tight container to avoid reoxidation. The off-gas from the reducer after serving to preheat the ore is led to a cyclone, waste-heat boiler and electrostatic precipitator to eliminate dust and recover waste heat. The gas is then cooled to 40°C to remove water vapour; make-up gas is added and, after recompression, the gas goes to a mono-ethanolamine tower to scrub out CO_2.

The differences to note in this process as against the H-Iron process are the higher temperature and lower pressure employed and the different method of obtaining the reducing gas.

A further process employing natural gas reduction, the Esso Research-Little process, is illustrated in Fig. 5. In this case the gas used is not recycled and a fast reaction rate is essential. Preheated natural gas and air are reacted to give a mixture of CO, H_2 and N_2, which reduces the fine iron ore in a fluidised-bed reactor. The ore is preheated before reduction to 850°C by burning a portion of the off-gas from the reducer, which also serves to preheat the natural gas and air and provides fuel for power plant.

Some other processes, currently being developed, may be very briefly mentioned:

The British Iron and Steel Research Association is experimenting with a process to produce a molten metallic product, if possible steel, by reaction of fine ore, coal and oxygen.

An American invention, the McWane process, is being developed by McDowells Inc. Partial reduction is here carried out on a Dwight-Lloyd sintering plant followed by electric refining.

The Ontario Research Foundation is carrying out experiments on a reduction method, known as jet smelting, where natural gas and oxygen are utilised to reduce and melt finely divided ore.

The Stelling process[24] carries out fluidised reduction of ore using a reducing gas of high CO content to produce

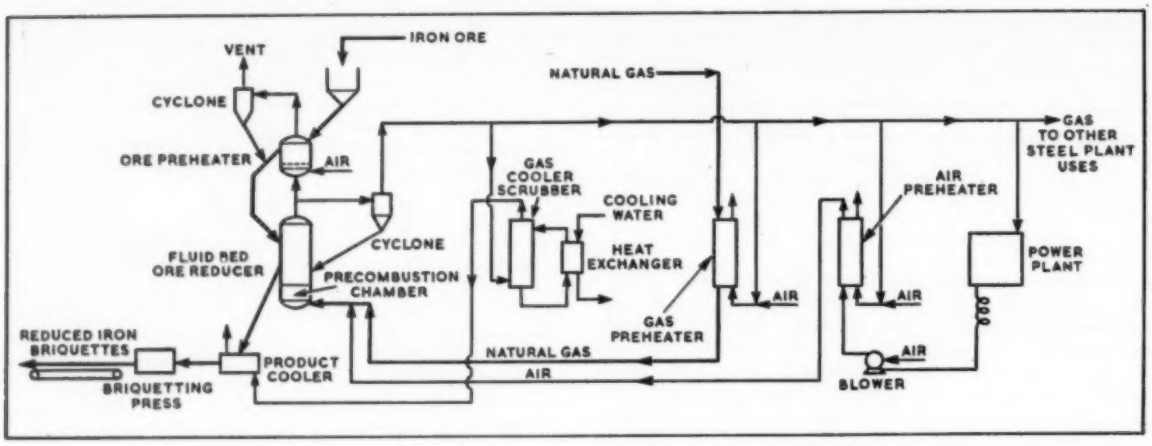


Fig. 5. Esso Research-Little process. (*Courtesy of A. D. Little Inc.*)

a maximum of cementite (Fe_3C) as the end-product, for use in a suitable steelmaking process.

In conclusion, it should be emphasised that none of the commercially-used ironmaking processes mentioned in this article should be considered "better" in an absolute sense than any other. Circumstances, however, may be such as to give one particular process widespread applicability whereas another may only be favoured under very special conditions. It is quite possible that some new ironmaking process, not yet used commercially, may become a large-scale producer in the fairly near future, for there has been much research work in this field in recent years. Thus a departure from classic ironmaking by the blast furnace is now looked on with considerably less scepticism than was the case about 10 years ago.

REFERENCES

[1] Chatterjea, A. B. *Iron and Coal Trades Review*, 1956, **173**, 1255-61 and 1329-35.
[2] Sauberlich, K. *Neue Hutte*, 1956, **1**, 193-201.
[3] Baake, R. Ibid., 202-15.
[4] Lux, H. J. Ibid., 216-25.
[5] *Revue Universelle des Mines*, 1957 (ninth series), **13**, 84-90.
[6] Paschal, F. *Centre de Documentation Siderurgique, Circulaires d'Information Techniques*, 1956, No. 9, 1771-3.
[7] *Revue Universelle des Mines*, 1955 (ninth series), **11**, 45-67.
[8] Coheur, P., Fouassin, M., and Frenay, E. *Revue Universelle des Mines*, 1953 (ninth series), **9**, 482-92.
[9] Reinfeld, H. *Iron and Coal Trades Review*, 1956, **173**, 1139-48.
[10] Johannsen, F. *A.I.M.M.E. Proceedings of Blast Furnace, Coke Oven and Raw Materials Conference*, 1952, 75-88.
[11] Henry, P. E., Ramseyer, C. F., and Miller, J. R. *Iron and Steel Eng.*, 1951, **28**, 66-78.
[12] Jensen, K. E. *Stahl und Eisen*, 1952, **72**, 1466-67.
[13] Hofmeister, H., and Herrmann, C. *Demag News*, 1953, No. 131, 1-11.
[14] Barrett, E. P. *U.S. Bureau of Mines Bulletin*, No. 519, 1954.
[15] Kalling, B., and Johansson, F. *J. of the Iron and Steel Inst.*, 1954, **177**, 76-85.
[16] Frick, F. F. *Mining Eng.*, 1953, 83-4.
[17] *Steel*, 1957, October 28, 180.
[18] Ektorp, S. *Jernkontorets Annaler*, 1945, **129**, 703-21.
[19] Cavanagh, P. E. *Metal Progress*, 1953, **63**, March, 67-9.
[20] Stalhed, J. *Stahl und Eisen*, 1952, **72**, 459-66.
[21] Kalling, B., and Stalhed, J. *Steel*, 1949, **125**, 72.
[22] Squires, A. M., and Johnson, C. A. *J. of Metals*, 1957, **9**, Section 1, 586-90.
[23] *British Chemical Engineering*, 1956, **1**, 424-7.
[24] Stelling, O. *J. of Metals*, 1958, **10**, April, 290-5.

BIBLIOGRAPHY

The following publications deal generally with ironmaking processes other than the blast furnace, and contain more detailed bibliographies than can be given here.

Astier, J. *La Documentation Metallurgique*, 1956, Special Number Shl 15 April, 75-96.
Cope, S. G. *Murex Review*, 1957, **1**, No. 17.
Durrer, R. *Verhutten von Eisenerzen*, 1954, Verlag Stahleisen, Düsseldorf.

Ammonia Absorption in a Packed Tower

AT A RECENT MEETING of the North-Western Branch of the Institution of Chemical Engineers at Manchester, a paper on "The Effect of Ammonia Absorption on the Wetted Area of a Packed Tower" was presented by DR. W. S. NORMAN and MR. B. SOLOMON.

The wetted area of the packing in an absorption tower depends on the rate of flow of the liquid over the surface of the packing and on the properties of the gas absorbed by the liquid from the carrier gas, usually air. From previous work on wetted-wall columns, it was known that the minimum wetting rate (MWR) for the liquid increased with increasing ammonia concentration in the gas and with increasing gas velocity, but decreased with increasing temperature of the liquid. DR. NORMAN described the work done by MR. SOLOMON and himself on the absorption of ammonia using a disc packing designed to reproduce in the laboratory the flow characteristics of a packed tower. The discs were supported edgewise on a vertical wire threaded through the diameter of each disc and every disc was placed at right angles to the one above and below it. The discs with rough or with smooth surfaces were supported in a vertical glass tube having an inlet and an outlet for gas at the bottom and top respectively. The wetted area of a disc was estimated by visual observation and comparison with a series of standard profiles for various wetted fractions of disc; the edges of the discs were always fully wetted.

The MWR was determined for three different gas velocities and the concentration of ammonia in the gas varied in stages up to 90%. Demineralised water was allowed to flow over the discs at a high rate and the flow gradually reduced until dry spots appeared on the discs; this was taken as the MWR for each test. The MWR reached a maximum at 20% ammonia in the gas, then it decreased by a small amount until it assumed a constant value between 40 and 90% ammonia. The effect of gas velocity on the MWR was less marked. The MWR for liquids containing 2, 9 and 17% ammonia decreased progressively with increases in the concentration of ammonia in the liquid. When, as in industry, the liquid rates were considerably below the MWR, the wetted area of the discs decreased as the ammonia concentration in the gas increased, but at gas concentrations over 50% ammonia the wetted area became constant or increased. The presence of ammonia in the liquid resulted in a marked increase in the wetted area.

The overall mass-transfer coefficients based on the wetted area were constant over a large range of liquid water rates and agreed with those obtained by previous workers.

661.723

A NEW PROCESS FOR CARBON-TETRACHLORIDE

FOR many years the major source of carbon tetrachloride has been the reaction of elemental chlorine with carbon bisulphide, but recently this process has been overtaken by the chlorination of methane, for which thermal or photochemical routes are available. Among thermal processes, the more important of the two, is a recent Roumanian development, which takes advantage of the very pure natural gas of the Transylvanian basin as well as chlorine derived from salt in the same area.[1]

In this process the reaction is carried out at 380 to 400°C in a reactor of the type shown in Fig. 1. Here part of the reacted gases are recirculated to the reactor by means of an ejector (8). Attached to the reactor is a methane combustion chamber for circulating hot gases through the reactor jacket to enable the reaction temperature to be attained at the start-up of the process. Once a reaction is in progress the exothermic heat of reaction is removed by the gases entering through the central tube, and the reaction temperature is controlled by the proportion of recycle gases in the reactor feed.

The reactor is constructed from cast iron lined with a layer of acid-resistant cement containing a high proportion of finely powdered quartz. The ejector makes use of the chlorine pressure for pumping the recycled gases to the reactor.

The main process steps are shown in Fig. 2. The reaction products are fed to a falling-film, cored-graphite column (3) which performs the dual function of a direct contact condenser for carbon tetrachloride and other chlorinated products, and of an absorber for hydrochloric acid. The remnants of hydrochloric acid are removed in a Raschig-ring packed column injected with water. The chlorinated products are separated from water by decantation, neutralised with caustic soda solution (5) and dried by solid caustic soda (6). Pure carbon tetrachloride is obtained by distillation (8), but before this step is taken phosphine is removed by the addition of benzidine which is added to the products during storage (7). The plant itself is arranged to give gravity flow in order to avoid the use of pumps.

The following balance, basis 1 mol. chlorine, is reported for the reaction stage

	Mol. Entering	*Mols. Leaving*
Cl_2	1	—
CH_4	0.2627	0.0045
CCl_4	—	0.0340
$CHCl_3$	—	0.2242
HCl	—	1.0000

To avoid explosive mixtures 5 to 6 mol. of gaseous products per mol. chlorine have to be recycled to the reactor and the resultant feed composition is:

CH_4,	0.0200 mol.
$CHCl_3$,	0.1410 mol.
CCl_4,	0.9369 mol.
HCl,	4.1671 mol.

The temperature of the reactants for a reaction temperature of 380°C is 18°C for chlorine and 140°C for the recycled gases. The heat of reaction is 23,291 kcal./kmol. chlorine and losses amount to 15% of the total heat entering the reactor.

The yield of chlorinated products is stated to be 95% based on chlorine; the capacity of the reactor is 2500-2800 Kg/hr per m.³ of reactor space when carbon tetrachloride is the product. The chlorine reacts completely and the gases discharged through the scrubber contain 1.5 to 2.5% only of methane. The process is a flexible one, since other chlorinated products in good yield can be obtained; thus methyl chloride and tetrachlorethylene can be produced, although the operating conditions for these products have not been given.

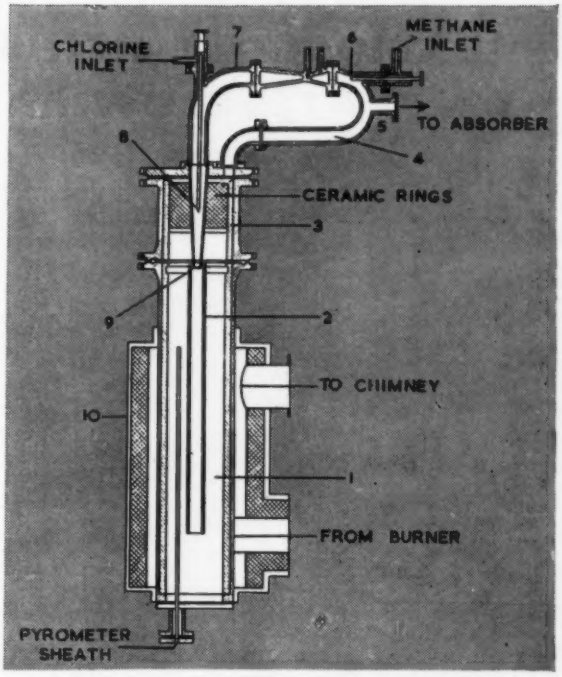


Fig. 1. Process reactor showing component parts.

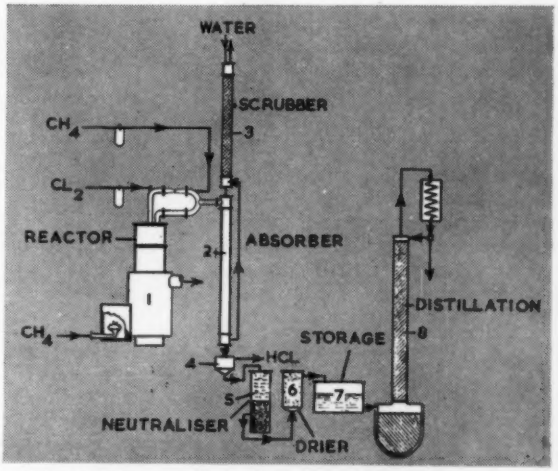


Fig. 2. Diagram illustrating the main process steps.

REFERENCE

[1] Ionescu, V., and Anghelescu, Ing. N. "A New Industrial Process for the Manufacture of Carbon Tetrachloride from Methane and Chlorine", *Revista de Chimie*, 1957, **12**, 745-9.

681.121:541.28

A RADIOACTIVE METHOD OF MEASURING LOW WATER-FLOW RATES

A description of a flowmeter designed for fluids at very low flow rates and at high pressure

by J. F. CAMERON, B.Sc.,* P. F. BERRY, B.Sc.,* and F. TAYLOR, A.M.I.Mech.E.†

Fig. 1a. Component parts of the flowmeter.

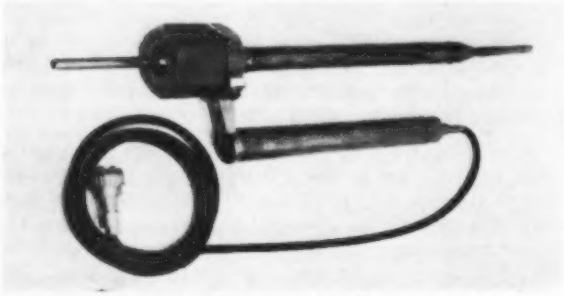


Fig. 1b. The assembled flowmeter.

A HIGH-PRESSURE loop using a canned-rotor-type centrifugal pump has been constructed for circulating thoria slurry at 300°C and 2000 psi. The information derived from this loop is necessary for the design of a homogeneous aqueous reactor. It is essential that the pump bearings should be flushed continuously with clean water to prevent slurry particles entering the bearings and reducing their useful life. The estimated minimum flow required for this purpose is 50 cc/min., and it is desirable that the flow-rate range, 0-70 cc/min., should be measured and recorded in this prototype equipment. As far as is known, no commercial instruments are available for this purpose (i.e., measurement of a small flow rate at high pressure) and, therefore, the instrument described below was developed.

Description of the Apparatus

This instrument uses a modified Rotameter type flowmeter in which the position of a radioactive float is measured by means of a scintillation counter. A standard glass Rotameter flowmeter with a range 0-100 cc/min. was enclosed in a $\frac{3}{4}$-in. o.d., 7 s.w.g. stainless-steel tube as shown in Fig. 2. The double O-ring seal at the base of the instrument prevents leakage into the annular space and since this is open to the discharge from the Rotameter tube the fluid is present on both sides of this tube which, therefore, is not under stress. An 80μc source of cobalt-60, in the form of a 3-mm length of 26 s.w.g. wire, was first sealed in a short length of thick-walled gold capillary tubing. This was then inserted into a hole drilled in the centre of the stainless-steel float and fixed by a screw which was afterwards centre-punched to lock it in position.

The height of the float is measured by means of a scintillation counter located outside the steel tubing. The counter consists of a 1-in. diameter × 1-in. long crystal of sodium iodide, and a photomultiplier (type 9524 E.M.I. Electronics Ltd.). The scintillation counter has the advantage over a Geiger counter or an ionisation chamber detector in that its sensitivity to the gamma radiation from cobalt-60 is higher by a factor of about 10, which means that a small source activity can be used.

* Isotope Division, A.E.R.E., Harwell.
† Reactor Division, A.E.R.E., Harwell.

Details of the mechanical construction of the flowmeter are given in Figs. 1a and 1b. The scintillation counter can be removed from the telescopic-brass tube for maintenance and for a check on the background activity in localities where other radioactive sources may be present. The telescopic-brass tube is brazed to a brass arm which is bolted to the stainless-steel tube enclosing and supporting the glass Rotameter tube. The gamma-ray count-rate is indicated in a counting-rate meter (Harwell type No. 1037A), after amplification in an amplifier type 1186A.

Typical curves showing count-rate versus float height are shown in Fig. 3. As the distance of the detector from the axis is increased so these curves become more nearly linear over a larger part of the measuring range: however, this is obtained at the expense of slope and, therefore, of accuracy. Higher activity is also required in the source when the detector is more distant and this is undesirable because of the radiation hazard. The chosen distance of 3 in. is a compromise. The final calibration curve relating flow rate to counting rate is shown in Fig. 4.

The accuracy of the flow-rate determination is limited by the statistical variation in the counting rate due to the random rate of emission of the radiation. The relative standard deviation in the detector output is $(2NRC)^{-\frac{1}{2}}$ where N is the average counting rate and RC is the time constant of the ratemeter circuit.[1, 2] These variations are small when a large-source activity and long time constants are used. To keep the radiation hazard to a minimum it is desirable to use a low-source activity, and the maximum time constant that can be incorporated depends on the rate of response required from the indicating unit.

As it is essential to incorporate a relay system to operate an alarm when the flow rate falls below a minimum level, the detector position along the axis is arranged so that the counting-rate indication increases with decreasing flow rate (which is not conventional flowmeter practice). With this arrangement maximum accuracy is obtained at low flow rates. Another relay which is actuated when the counting rate falls to zero is incorporated as a fail-safe device. The time constant to be used depends on the rate of fall of the float; the time taken for the float to fall from 50 cc/min. to 25 cc/min. is about 4 sec., and a time constant of 0.5 sec. is therefore used. With this time constant the relative standard deviation in the counting rate at a flow rate of 50 cc/min. corresponds to an error of ± 1 cc/min. in the measurement of flow rate. This accuracy can only be obtained with the high-counting rate of the order of 5000/sec., and the use of a Geiger counter detector with its associated simple auxiliary electronics is therefore impossible as it has a maximum counting rate of about 1000/sec.

The beta radiation emitted from the cobalt-60 is completely stopped by the containing glass and metal tubing, and the dose rate 12 in. from the surface of the outer metal case is 1.2 mr/hr. This compares favourably with the recommended tolerance dose of 300 mr/week of 40 hr for "persons employed in the process" and 30 mr/week for "persons not involved in the process";[3] the radiation hazard therefore is negligible. Extensive tests for leakage were carried out on the source enclosed in a gold capillary tubing. It was boiled in water for a total of 150 hr in a small Pyrex beaker. The water was evaporated to dryness in the beaker and the residue assayed frequently. No significant leakage was detected before or after it was subjected to a pressure test of 4000 psi in an autoclave. Thus there is no possibility of contamination.

ACKNOWLEDGMENTS

The authors acknowledge theassistance of Mr. A. R. E. Nicod and the suggestion by Mr. R. W. Murdoch that this work should be done.

REFERENCES

[1] Whitehouse, W. J., and Putman, J. L. "Radioactive Isotopes," Clarendon Press, London, 1953 p. 222.
[2] Schiff, L. I., and Evans, R. D. *Rev. Sci. Instr.*, 1936, 7, p. 456.
[3] Factories (Ionising Radiations) Special Regulations. H.M.S.O., 1957.

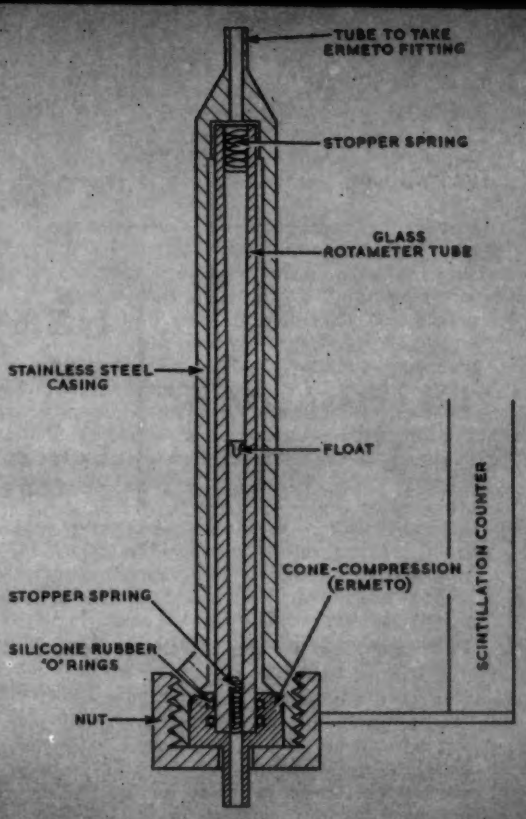


Fig. 2. Constructional details of the flowmeter.

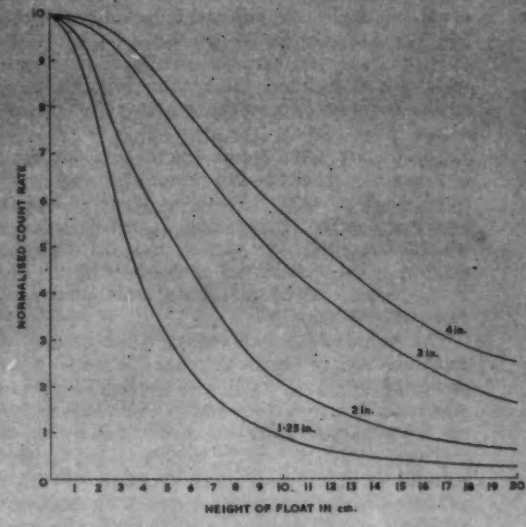


Fig. 3. Curves for count rate versus float height.

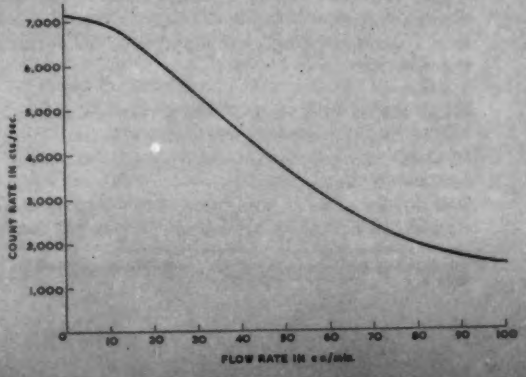


Fig. 4. Calibration versus flow rate counting rate.

HEAT TRANSFER TO BOILING BINARY LIQUID MIXTURES–PART II*

by S. J. D. VAN STRALEN

Experimental procedure and results obtained at high pressures are given by the author

Procedure and Results at Higher Pressures

2.1. METHOD AND APPARATUS.

2.1.1. STAINLESS-STEEL BOILING VESSELS.

In principle the two stainless-steel boiling vessels used for experiments at higher pressures were similar to the glass boiling vessel of Fig. 1. A diagram of the first stainless-steel vessel is shown in Fig. 13. Physically pure heating wires with diameters of 0.02 cm. were again used, but the test sections were extended to the whole length of the wires (approximately 6 cm.), as no potential taps were joined to them. This is justified by the random distribution of active nuclei on the entire heating surface (compare Fig. 12) and since the electrical resistance of the relatively thick stainless-steel bars was small in comparison with the resistance of the thin wires. Moreover, MCADAMS *et al.*[12] have not found any influence of wire length on heat-flux values to water.

The boiling vessel was wrapped by a detachable insulation jacket of asbestos and heated from below by an electrical heater with adjustable power. The maximum attainable water temperature in the vessel was 183°C, which corresponds to a vapour pressure of 11 atma.[5] These maximum values were not determined by the construction of the vessel, but by the limited maximum power of the heater (1200 watts).

The seamless second stainless-steel boiling vessel was provided with an electrical bottom heater with a maximum power of 1450 watts and with an auxiliary heater with a maximum power of 1150 watts, which was wrapped round the lower part of the vessel wall. A maximum water temperature of 265°C, corresponding to 52 atma, could be reached in this vessel. The thickness of the steel wall amounted to 1.0 cm., the thickness of the bottom to 1.5 cm., and the inner diameter to 8 cm. In this case heating wires with a length of approximately 4 cm. were used.

The first and second stainless steel vessels were partly filled with approximately 900 and 375 $cm.^3$ liquid respectively, corresponding to a liquid level of 7.5 cm. at room temperature.

2.1.2. MEASUREMENT OF BOILING TEMPERATURES.

The liquid temperatures were measured with mercury-in-glass thermometers, which were calibrated by total immersion, and placed in a stainless-steel tube (Fig. 13). The lower part of this tube was filled with lead (first stainless-steel boiling vessel) or silicone oil (second stainless-steel boiling vessel) in order to improve the conduction of heat to the thermometer bulb.

The observed temperatures T_o were corrected, according

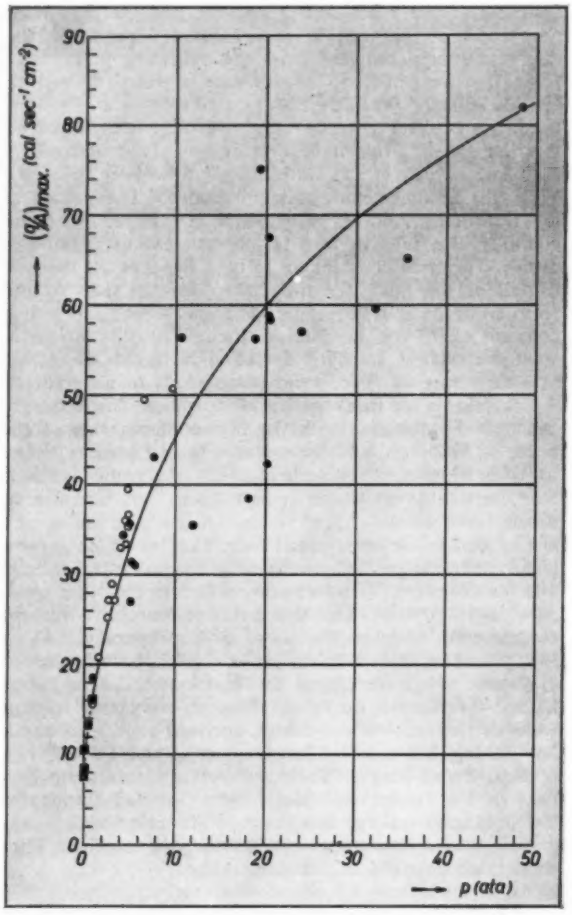


Fig. 14. Heat flux for convection and nucleate boiling to water as a function of temperature difference between heating surface and liquid at atmospheric pressure (□○ glass boiling vessel, ■ first stainless-steel boiling vessel) and at a pressure of 2.7 atma (● first stainless-steel boiling vessel).

* *The first part of this article was published in the January, 1959, issue, page 8.*

to the equation:

$$T_c = T_o + \triangle T_1 + \triangle T_2,$$

where T_c = corrected temperature, $\triangle T_1$ = calibration error, and $\triangle T_2$ = stem correction, due to the partial immersion of the thermometers, which was calculated from:

$$\triangle T_2 = 0.000157\ (T_o - 20)n,$$

with n = the number of degrees emergent from the lead or silicone oil.

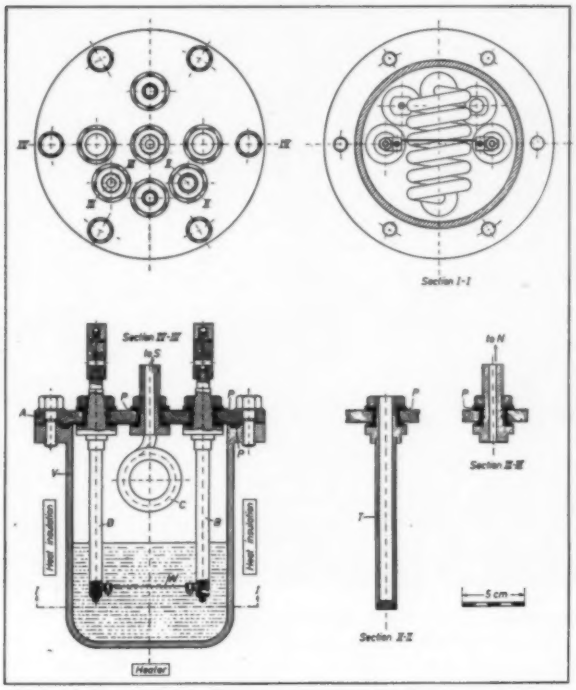


Fig. 13. Diagram of first stainless-steel boiling vessel. A = stainless steel (s.s.) cover; B = s.s. bars; C = s.s. water-cooled total reflux condenser; N = s.s. pressure gauge, nitrogen cylinder and s.s. Cartesian manostat (at pressures below 4 atma); S = s.s. safety valve; T = s.s. thermometer tube; V = s.s. vessel; W = heating wire.

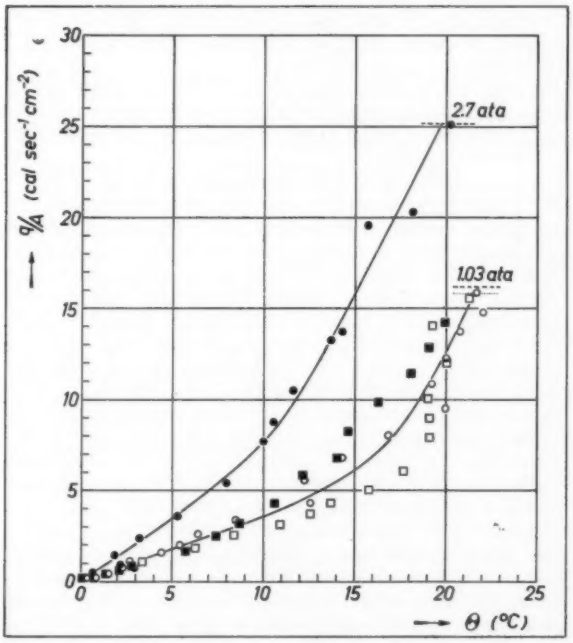


Fig. 15. Maximum of nucleate boiling to water as a function of pressure (■ glass boiling vessel, ○ first stainless-steel boiling vessel, ● second stainless-steel boiling vessel).

A set of stainless-steel pressure gauges with scales ranging from 1-5, 1-15, 1-30 and 1-60 atma respectively were used. The average error $T_p - T_c$ of the corrected temperatures T_c amounted in water (Table 2) to 3.4°C for measurements from 1-10 atma (first stainless-steel boiling vessel) and to 2.1°C for measurements from 1-50 atma (second stainless-steel boiling vessel), where T_p = boiling temperature corresponding to the observed pressure p, according to the water vapour pressure table.[5] The superheating of the boiling liquid, which amounts to some tenths of a degree centigrade at atmospheric pressure and diminishes gradually with increasing pressure,[7] has been neglected here.

The positive average difference $T_p - T_c$ can partly be attributed to the occurrence of a temperature gradient in the wall of the thermometer tube, and partly to deviations of the pressure gauges. Some calibration runs were carried out,* in order to check the second stainless-steel boiling vessel, by means of a silver-soldered copper-constantan thermocouple which was calibrated carefully up to 350°C. This thermocouple was led through the bottom of the thermometer tube into the water. These measurements were accurate within 2.0°C, e.g., $p = 23.13$ atma, $T\sigma = 217.0$°C, while $T_p = 218.9$°C. The maximum attainable water temperature in the second stainless-steel vessel, due to the limited power of the electrical heaters (section 2.1.1), was also determined in these runs.

The boiling of the liquids was ensured by the above-mentioned experiments.

2.1.3. Procedure

In obtaining a maximum nucleate boiling-heat flux, the heater power was set and the inert gas (nitrogen) and the water cooling adjusted to regulate the rate of condensation, i.e., to attain the desired pressure and corresponding boiling temperature. As the experiments in the boiling liquids were carried out rapidly, the pressure and temperature increased only slightly when the heat flux of the wire was increased up to the maximum value; the average increase in T_c was restricted to approximately 1.5°C. In the Tables 2-9 the average values of p and T_c are shown.

2.2. Results.

2.2.1. Comparison of Heat Flux Data for Water, Obtained with Different Boiling Vessels.

In Fig. 14 the heat flux to boiling water is shown as a function of the temperature difference between heating surface and liquid at atmospheric pressure and at a pressure of 2.7 atma. These measurements were carried out with platinum wires, heated by direct current, in the glass boiling vessel and in the first stainless-steel boiling vessel respectively. The agreement of the results at atmospheric pressure was fair, and the curve obtained at 2.7 atma, which was determined under constant pressure with the aid of the Cartesian manostat, joins the curves of Fig. 2.

Fig. 15 shows the maximum of nucleate boiling-heat flux, which was determined with alternating current heated platinum wires for water as a function of pressure. Again the data, obtained in different boiling vessels, tally fairly with each other. The maximum of nucleate boiling to water increases gradually with increasing pressure in the region investigated, in concurrence with the data of Addoms[9] and Kazakova.[10] This result is also in agreement with the theoretical considerations of sections 1.2.1.1. and 1.2.2.4.2. A complete survey of the data of Fig. 15, con-

* *The author is indebted to Mr. R. Altmann of the Stichting Landbouw Fysisch Technische Dienst for carrying out these measurements.*

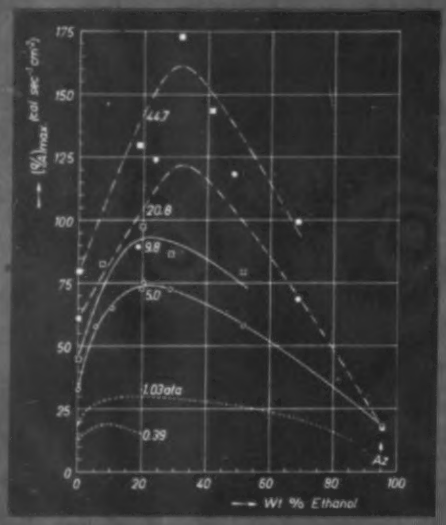


Fig. 16. *Water-ethanol. Maximum heat flux as a function of composition at 0.39 atma, 1.03 atma—glass boiling vessel—, 5.0 atma (○), 9.8 atma (□)—first stainless-steel boiling vessel—, 20.8 atma (●) and 44.7 atma (■)—second stainless-steel boiling vessel—. Az = azeotrope at atmospheric pressure.*

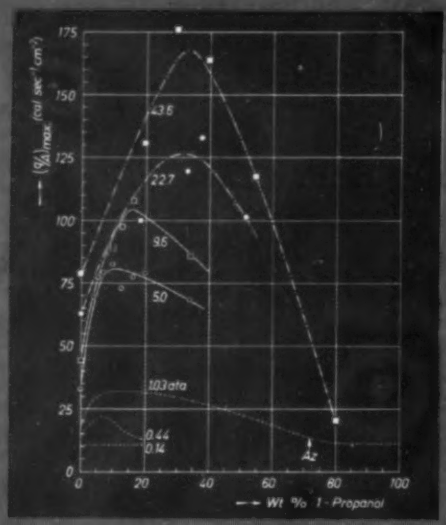


Fig. 17. *Water-1-propanol. Maximum heat flux as a function of composition at 0.14 atma, 0.44 atma, 1.03 atma—glass boiling vessel—, 5.0 atma (○), 9.6 atma (□)—first stainless steel boiling vessel—, 22.7 atma (●) and 43.6 atma (■)—second stainless-steel boiling vessel—. Az = azeotrope at atmospheric pressure.*

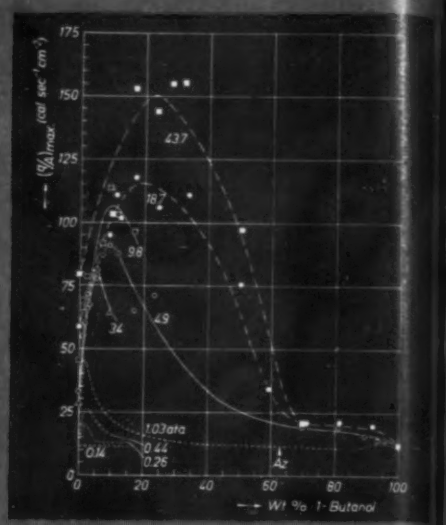


Fig. 18. *Water-1-butanol. Maximum heat flux as a function of composition at 0.14 atma, 0.26 atma, 0.44 atma, 1.03 atma—glass boiling vessel—, 3.4atma (△) 4.9 atma (○), 9.8 atma (□)—first stainless-steel boiling vessel—, 18.7 atma (●) and 43.7 atma (■)—second stainless-steel boiling vessel—. Az = azeotrope at atmospheric pressure.*

cerning pressure, boiling temperature and maximum nucleate boiling-heat flux to water, is shown in Table 2.

2.2.2. Maximum Nucleate Boiling-heat Flux as a Function of Binary Mixture Composition.

The maximum of nucleate boiling has been determined as a function of liquid composition for the binary systems water-ethanol (Fig. 16 and Table 3), water-1-propanol (Fig. 17 and Table 4), water-1-butanol (Fig. 18 and Table 5), water-1-pentanol (Fig. 19 and Table 6), water-acetone (Fig. 20 and Table 7), water-M.E.K. (Fig. 21 and Table 8) and water-ammonia (Fig. 22 and Table 9) at different pressures in the range from 1-50 atma.

These investigations have been carried out with the stainless-steel boiling vessels; the values obtained at atmospheric and sub-atmospheric pressures[20, 16] have been included as reference values (compare section 1.2).

It may be remarked, that for the system water-acetone at a pressure of 44.4 atma, a heat decomposition of the acetone occurred in 10.42% ($T_c = 245°C$), 30.16%, 40.04% and 49.15% wt of acetone ($T_c = 230°C$). Only in 10.42% wt of acetone were the heating wires contaminated, which resulted in a higher maximum nucleate boiling-heat flux (Fig. 20; compare section 1.2.2.3). In 64.73% wt of acetone ($T_c = 225°C$) film-boiling of the heating wire occurred, but at the point where the maximum nucleate boiling-heat flux had been obtained previously.

In the system water—M.E.K. at a pressure of 42.7 atma, a heat decomposition of the M.E.K. occurred also for 17.77% and 32.53% wt of M.E.K. ($T_c = 235°C$), but there was no contamination of the heating wires. In all other experiments no decomposition of the organic component or contamination of the heating surface occurred.

The maximum of nucleate boiling-heat flux for mixtures, containing water in excess, increased gradually with increasing pressure (Figs. 16, 17, 18, 19, 20, 21 and 22), similarly as for water (Fig. 15). On the other hand this is not the case for mixtures containing the organic component in excess; e.g., the maximum nucleate boiling-heat flux to pure acetone amounts to 10.65 cal. sec.$^{-1}$ cm.$^{-2}$ at a pressure of 18.5 atma and to 6.31 cal. sec.$^{-1}$ cm.$^{-2}$ at a pressure of 40.4 atma (Fig. 20 and Table 7). This is in accordance with the correlation of Cichelli and Bonilla[3] for pure organic liquids, as the critical pressure of acetone amounts to 48 atma.

The maxima in the curves are shifted towards a higher concentration of organic component with increasing pressure (Figs. 16, 17, 18, 19, 20, 21 and 22); at the same time a broadening of the maxima occurs with increasing pressure (compare section 2.3). The second maxima, occurring at a high concentration of 1-butanol and 1-pentanol (Figs. 18 and 19; compare section 1.2.2), are of less importance.

2.2.3. Maximum Attainable Heat Flux to Mixtures at Pressures from 20-50 atma in Comparison with Maximum Heat Flux to Water at an Arbitrary Pressure.

The maximum heat-flux correlation for organic liquids of Cichelli and Bonilla,[3] who used an electrically-heated horizontal copper plate with polished chromium surface, can be assumed to be also valid for water, according to Addoms[9] and Kazakova,[10] who used electrically-heated platinum wires with diameters of 0.06 cm. and 0.15 cm. respectively. For a chromium surface in water one finds from this correlation a maximum in maximum heat flux value of 86 cal. sec.$^{-1}$ cm.$^{-2}$ at a pressure of 50 atma, and a maximum in maximum heat flux of 92 cal. sec.$^{-1}$ cm.$^{-2}$ at a pressure of 75 atma (i.e. reduced pressure $p_r = 0.33$) as the critical pressure p_c of water amounts to 225 atma.[5] From Fig. 15 follows 82 cal. sec.$^{-1}$ cm.$^{-2}$ for a platinum surface in water at a pressure of 50 atma, and Addoms[9] found a maximum heat flux of 120 cal. sec.$^{-1}$ cm.$^{-2}$ at a pressure of 115 atma. In water-1-propanol (Fig. 17), e.g., a maximum nucleate boiling-heat flux of 165 cal. sec.$^{-1}$ cm.$^{-2}$ occurs at a pressure of 43.6 atma. *As a consequence, maximum heat flux values in nucleate boiling can be obtained with binary mixtures boiling in the range from* 20-50 *atma, exceeding considerably the maximum values, which are attainable with water boiling at an arbitrary pressure on the same heating surface.*

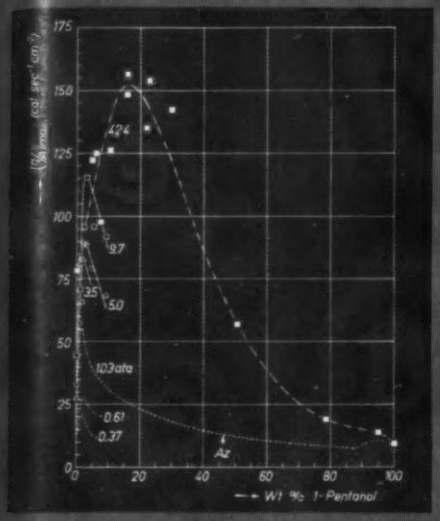


Fig. 19. Water-1-pentanol. Maximum heat flux as a function of composition at 0.37 atma, 0.61 atma, 1.03 atma —glass boiling vessel—, 3.5 atma (△), 5.0 atma (○), 9.7 atma (□)—first stainless-steel boiling vessel—and 42.4 atma (■)—second stainless-steel boiling vessel—. Az = azeotrope at atmospheric pressure.

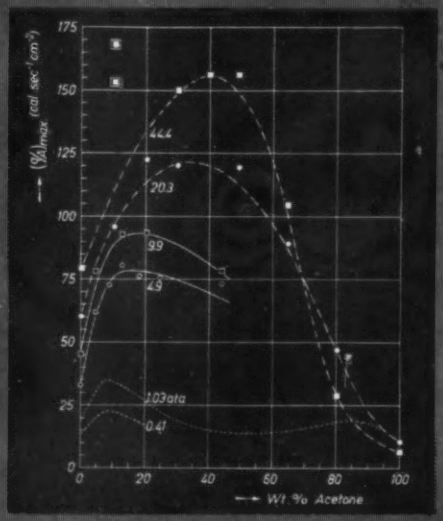


Fig. 20. Water-acetone. Maximum heat flux as a function of composition at 0.41 atma, 1.03 atma—glass boiling vessel—, 4.9 atma (○), 9.9 atma (□)—first stainless-steel boiling vessel—, 20.3 atma (●) and 44.4 atma (■ ⊟)—second stainless-steel boiling vessel—. The relatively high values of heat flux in 10.42% wt. of acetone at 44.4 atma (⊟) can be attributed to contamination of the heating surface due to a heat decomposition of the acetone.

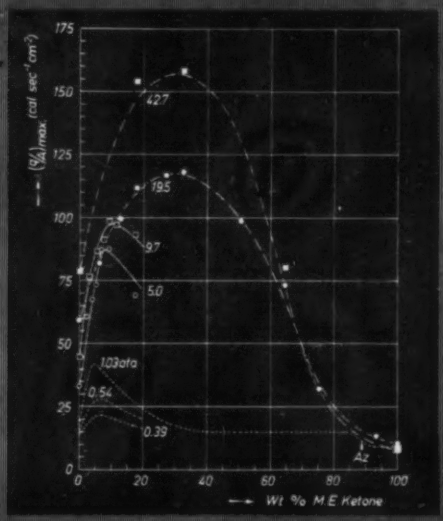


Fig. 21. Water-methylethylketone. Maximum heat flux as a function of composition at 0.39 atma, 0.54 atma, 1.03 atma—glass boiling vessel—, 5.0 atma (○), 9.7 atma (□)—first stainless-steel boiling vessel—, 19.5 atma (●) and 42.7 atma (■)—second stainless-steel boiling vessel—. = maximum heat flux to methylethylketone at 33.8 atma. Az = azeotrope at atmospheric pressure.

2.2.4. Influence of Different Heating Surface on the Maximum of Nucleate Boiling in Water and in Binary Mixtures.

With an oxidised nichrome *V* wire (diameter 0.05 cm.), a maximum heat flux to water of 40.79 cal. sec.$^{-1}$ cm.$^{-2}$ was reached at atmospheric pressure, and of 98.08 cal. sec.$^{-1}$ cm.$^{-2}$ at a pressure of 13.33 atma (corrected observed boiling temperature $T_c = 190.4°C$ and $T_p = 191.9°C$). In 13.87% wt of M.E.K. ($p = 12.73$ atma and $T_c = 168.3°C$) a maximum nucleate boiling-heat flux of 120.08 cal. sec.$^{-1}$ cm.$^{-2}$* was reached with a nichrome *V* wire of identical dimensions. These experiments have been carried out in the second stainless-steel boiling vesel.

So the effect of obtaining higher maxima in binary mixtures, containing a most volatile component, appears to be also present at higher pressures, independent of the constitution of the heating surface (compare sections 1.2.2.3. and 1.2.2.4.2.).

2.2.5. Ratio of Maximum Heat Flux in Mixtures to Corresponding Value in Water.

The influence of pressure on the ratios of the nucleate-boiling maxima for mixtures to the corresponding value for water at the same pressure is shown in Figs. 23 and 24. Maximum ratios between 2.3 and 3.1 occur for the systems investigated at relatively low pressures between 1 and 10 atma. With increasing pressure, all ratios approximated a value of 2.0 in the range from 10-50 atma.

2.3. Theoretical Considerations.

In connection with the qualitative explanation of the occurrence of a minimum average size of vapour bubbles (section 1.2.2.4.1.), resulting in higher maximum heat-flux values (section 1.2.2.4.2.) at certain concentrations of binary systems containing a very volatile component, the $\triangle T$-curves have been calculated for the system water-M.E.K. at a pressure of 35.1 atma, from equilibrium data of Othmer, *et al.*[14] Fig. 25 shows these curves and those at atmospheric pressure for constant values of the vaporised molar fraction *G*.

With increasing pressure a shift of the curves for $G = 0.01$ towards decreasing values of $\triangle T$ occurs, while the maxima of the $\triangle T$-curves are broadened at the same time, in concurrence with the behaviour of the maximum heat-flux curves of Figs. 16, 17, 18, 19, 20, 21 and 22 (section 2.2.2). The superheating of boiling water decreases from 0.6°C at atmospheric pressure to 0.3°C at a pressure of 35 atma, according to Jakob and Fritz.[7]

In order to compensate this superheating in certain concentrations of the water-M.E.K. mixtures at 35 atma, according to Equation (7) of section 1.2.2.4.1., one must assume that the selected value for *G* of 0.002 (Fig. 7) at atmospheric pressure increases to at least 0.005 at 35 atma. This means that the molar fraction, which is vaporised immediately at a heating surface, increases with increasing pressure in the range investigated. In agreement with this statement, the increase in the ratio of the maximum heat flux values in mixtures to the corresponding values in water with increasing pressure in the range from 0.1-1 atma can be explained (compare section 1.2.2.2 and Figs. 9 and 10).

It may be remarked that the observed shift of the maxima in the maximum heat-flux curves at higher pressures towards a higher concentration of organic component, is also partly due to the increasing vapour capacity of the vapour space in the boiling vessel. It is estimated from the available equilibrium data,[14] that the observed heat flux maximum, e.g., at a pressure of 42.7 atma (Fig. 21 and table 8), which occurred at 32.5% wt of M.E.K. (i.e., original concentration at room temperature), shall actually occur at a concentration of approximately 31% wt of M.E.K. in the boiling liquid. Obviously this effect is of less importance and this supports ultimately the statement that the molar fraction, which is vaporised immediately at the heating surface, increases with increasing pressure in the range investigated.

* *One gets the impression, that the effect of obtaining higher absolute heat-flux maxima with a different, i.e., oxidised, heating surface, diminishes with increasing pressure, when a certain limit of maximum heat-flux value is exceeded.*

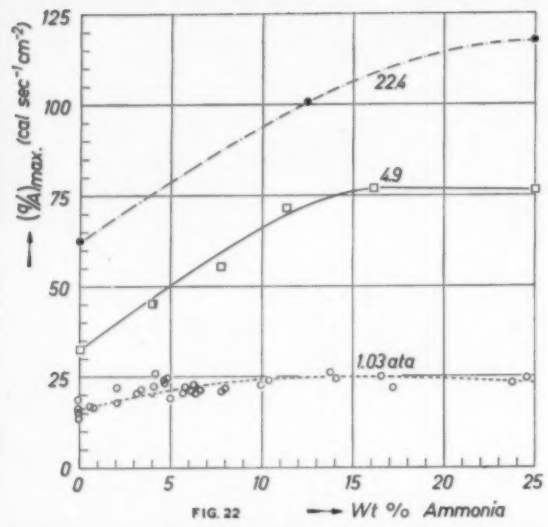


FIG. 22

Fig. 22. Water-ammonia. Maximum heat flux as a function of composition at 1.03 atma (○)—glass boiling vessel—4.9 atma (□)—first stainless-steel boiling vessel—and 22.4 atma (●)—second stainless-steel boiling vessel.

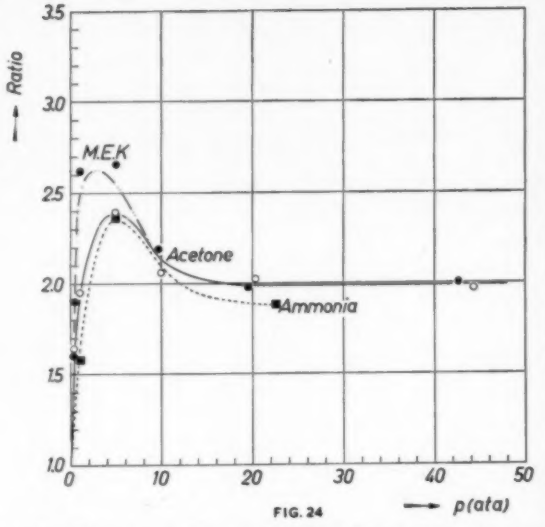


FIG. 24

Fig. 24. Water-acetone (○), water-methylethylketone (●) and water-ammonia (■). Ratio of maximum in maximum heat flux for mixtures to corresponding value for water as a function of pressure.

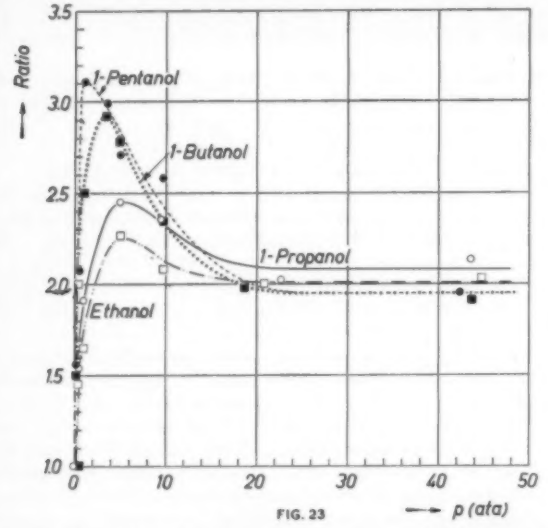


FIG. 23

Fig. 23. Water-ethanol (□), water-1-propanol (○), water-1-butanol (■) and water-1-pentanol (●). Ratio of maximum in maximum heat flux for mixtures to corresponding value for water as a function of pressure.

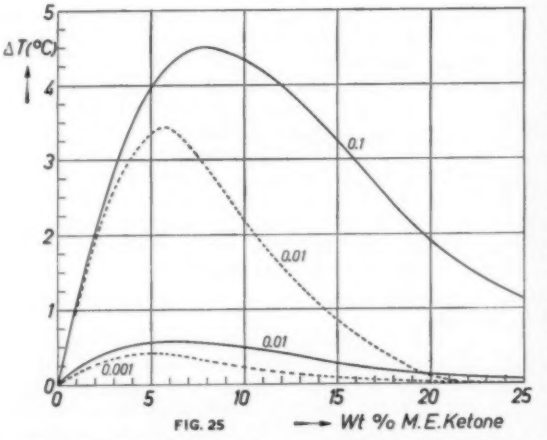


FIG. 25

Fig. 25. Water-methylethylketone. ΔT as a function of composition for a constant vaporised molar fraction G at 1.03 atma (— — — — —) and 35.1 atma (————). ΔT is the difference between dew temperature of the vapour bubbles and boiling temperature of the original liquid. The numbers near the curves are the values of G.

ACKNOWLEDGMENTS

The investigation of studying liquid boiling by slowing down the growth rate of vapour bubbles in liquid mixtures was suggested by PROF. DR. W. R. VAN WIJK. The Stichting voor Fundamenteel Onderzoek de Materie, which is a division of the Stichting voor Zuiver Wetenschappelijk Onderzoek, The Hague, Netherlands, has supported the investigation with an important grant. MR. L. VAN DEN BERG made a literature research and did some preliminary experiments. The author is indebted to Marshallgelden voor de Landbouwhogeschool for a grant which made it possible for him to join the staff of the laboratory at Wageningen.

REFERENCES

[1] Bonilla, C. F., and Perry, C. W. *Trans. Amer. Inst. Chem. Eng.*, 1941, **37**, 685-705.
[2] Burgess, G. K., and Chatelier, H. le. "The Measurement of High Temperatures", 3rd ed., John Wiley & Sons, New York, 1912, 197; 493-495.
[3] Cichelli, M. T., and Bonilla, C. F. *Trans. Amer. Inst. Chem. Eng.*, 1945, **41**, 755-787; 1948, **42**, 411-412.
[4] Forster, H. K., and Zuber, N. *J. Appl. Phys.*, 1954, **25**, 474-478.
[5] Hodgman, C. D. "Handbook of Chemistry and Physics", 30th ed., Chemical Rubber Publishing Co., Cleveland, Ohio, 1946, 1829-1831.
[6] Jakob, M. "Heat Transfer", Volume I, John Wiley & Sons, New York, Chapman & Hall, London, 1950, 632-633.
[7] Jakob, M., and Fritz, W. *Physik. Zeitschr.*, 1935, **36**, 651.
[8] McAdams, W. H. "Heat Transmission", 3rd ed., McGraw-Hill Book Company Inc., New York, Toronto, London, 1954, 370.
[9] Ibid., 382.
[10] Ibid., 385.
[11] Ibid., 391.
[12] McAdams, W. H., Addoms, J. N., Rinalde, P. M., and Day, R. S. *Chem. Eng. Prog.*, 1948, **44**, 639-646.
[13] Othmer, D. F., and Benenati, R. F. *Ind. Eng. Chem.*, 1945, **37**, 299-303.
[14] Othmer, D. F., Chudgar, M. M., and Levy, S. L. *Ind. Eng. Chem.*, 1952, **44**, 1872-1881.
[15] Piesset, M. S., and Zwick, S.A. *J. Appl. Phys.*, 1954 **25**, 493-500.
[16] Stralen, S. J. D. van *Chem. Eng. Sci.*, 1956, **5**, 290-296.
[17] Strong, J. "Procedures in Experimental Physics", Prentice-Hall Inc., New York, 1947, 127.
[18] Vos, A. S., and Stralen, S. J. D. van *Chem. Eng. Sci.*, 1956, **5**, 50-56.
[19] Wijk, W. R. van, *Dechema Monographien*, 1956, **28**, 63-74.
[20] Wijk, W. R. van, Vos, A. S., and Stralen, S. J. D. van, *Chem. Eng. Sci.*, 1956, **5**, 68-80.

66.065.511

THE WETTED-WALL COLUMN AS AN EVAPORATIVE CRYSTALLISER

High mass-transfer rates with economy in power consumption are features of this parallel-flow evaporator

by J. L. CHANDLER, B.Sc.(Eng.), A.M.I.Chem.E.

FROM data obtained by the vaporisation of nine different liquids in a wetted-wall column, GILLILAND[1] was able to show that x, the effective film thickness which would offer the same resistance to molecular diffusion as that obtained in the vaporisation, was given by the equation:

$$\frac{D}{x} = 0.023\ (\mathrm{Re})^{0.83}\ (\mathrm{Sc})^{0.44}$$

where D = diffusivity and Sc = Schmidt number.

As the mass-transfer coefficient for the gas film, $k_G a$ is inversely proportional to the film thickness, it follows that $k_G a$ varies as $\mathrm{Re}^{0.83}$. Thus a wetted-wall column could act as an efficient evaporator if a very high Reynolds number is used; e.g., if an Re of 200,000 is used for the gas flow instead of 20,000, the value of $k_G a$ will be multiplied by 6.75.

With Reynolds numbers of this order only parallel flow can be used, since the liquid will not flow under gravity in the opposite direction to such a high-velocity gas stream. However, this is not necessarily a disadvantage. If, in any mass-transfer operation, the aim is to achieve the maximum mass-transfer rate rather than the maximum or minimum concentration in the gas stream, the lower driving force of parallel-flow operation can often be more than offset by the high mass-transfer coefficient which results when a high Reynolds number can be used.

To illustrate this point Fig. 1 has been prepared. It shows the ratio of driving force in parallel flow to driving force in countercurrent flow for the same mass or heat transfer. The parameters of Fig. 1 (a) refer to the parallel and countercurrent systems compared in Fig. 1 (b) where a, b and c are the change in stream A, the change in stream B, and the difference between the outlet conditions of streams A and B respectively. For comparable stream-flow rates the countercurrent system will have the same overall mass- or heat-transfer rate as the parallel system, the changes in temperature or concentration of the streams being the same in both cases. Thus the ratio of the interfacial areas required in each system will be inversely proportional to the ratio of the driving forces. If for example, the outlet difference (c) is 1% of the inlet difference ($a + b + c$), reference to Fig. 1 (a) shows that the countercurrent system cannot have a driving force of more than 1/0.425, or 2.35 times that of the parallel-flow system. (This is the maximum ratio of the driving forces, and occurs when a and b are equal. When one stream changes in temperature or concentration more than the other, the ratio is lower.) If the mass-transfer coefficient which can be achieved in parallel flow is more than 2.35 times that which can be achieved in countercurrent flow, the parallel system has an advantage as a mass-transfer device. From the application of GILLILAND'S relationship, it is apparent that the parallel-flow wetted-wall column is one device in which the high k_G value can more than offset the higher driving force of the countercurrent wetted-wall column, as the gas-flow Reynolds number of the latter is limited.

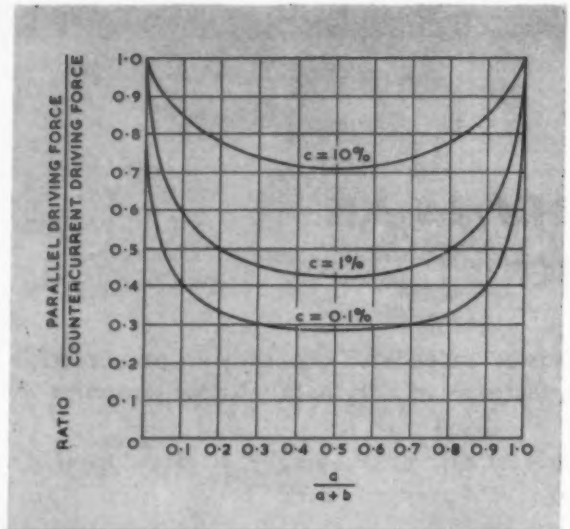
Mr. J. L. Chandler *graduated in Chemical Engineering at London University in* 1952, *and was Chief Chemist of the Demerara Bauxite Co., British Guiana, until* 1954, *when he joined the staff of the University College of the West Indies.*

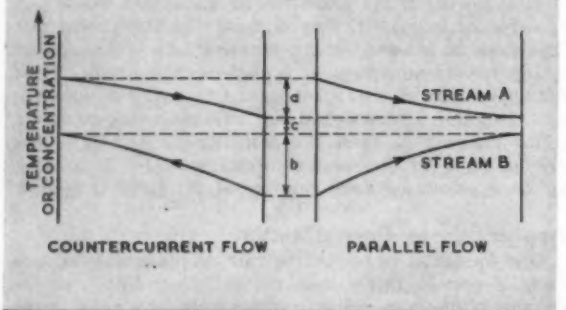
Application to Crystallisation

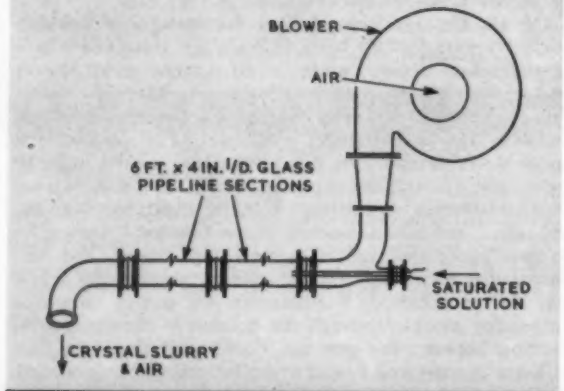
One operation in which the rate of mass transfer is a more important factor than the outlet conditions of the streams is the evaporative crystallisation of a solute from a hot saturated solution by contact with air. So long as the back pressure on the air is low, the cost of the air is insignificant, and there is little point in completely saturating the air. On the other hand, a very large volume of air is required to evaporate a small amount of solvent, which means that a large and costly contacting device is required unless the mass-transfer coefficient is very high.

Of all the available devices for gas-liquid contact, packed towers and all types of trays are ruled out where crystallisation occurs while countercurrent spray towers and countercurrent wetted-wall columns have low mass-transfer coefficients due to the limited gas flow Reynolds number. The mass-transfer coefficient of a parallel-flow spray tower is also low, due to the low relative velocity below the gas and the droplets. As against these devices, the parallel-flow wetted-wall column apparently has advantages. Due to the viscosity of the solution it cannot be carried along the wall at a very high speed, and this means that a very high relative velocity between liquid and gas can be achieved. Furthermore, the power consumed in passing the gas through the column is entirely due to friction between the gas and liquid, and therefore contributes to mass and heat transfer instead of being wasted.

From the above considerations it was anticipated that a wetted-wall column might yield good results on the evaporative crystallisation of a solution of crude salt to produce a pure fine-grained salt for domestic use. How-







ever, as the experiments from which GILLILAND'S equation was obtained used Reynolds numbers only up to 23,000, it was felt that extrapolation up to the order of 200,000 could not be done with confidence. A pilot-plant-scale evaporative crystalliser, using the wetted-wall column principle, was set up to check the anticipated performance.

Pilot-plant Studies

Fig. 2 shows the arrangement of the wetted-wall column for evaporative crystallisation. The column itself consists of a horizontally-disposed 4-in. i.d. glass pipeline. Air is led into this from a blower by means of a 4-in. i.d. glass bend. The bend is fitted with a 1-in. i.d. side arm so that the solution can be led axially into the column, through a ¼-in. i.d. glass tube inserted through the side arm. It was found unnecessary to fit this feed tube with any sort of nozzle to distribute the solution, as the high-velocity gas stream was found to disintegrate the solution stream effectively and spread it round the inside of the column. This arrangement of the air and solution feeds offers a very low resistance to the air flow. (To lead the air straight into the column instead of through a bend would offer less resistance, but difficulties would be encountered due to solution flowing back into the blower, if the latter stopped for any reason.)

The crystalliser was incorporated into a recrystallisation process, as shown in the flowsheet (Fig. 3). The heater, consisting of an open tank with a 15-in.-dia. firetube passing through it, maintained the solution at saturation and at its boiling point, and for ease of control propane gas was used in the firetube. The hot solution was filtered through a pressure filter and fed to the wetted-wall evaporative crystalliser. The slurry from the crystalliser was led tangentially into a cylindrical vessel, this acting as a cyclone to separate the slurry from the air. After thickening and centrifuging the slurry, the mother liquor was recycled to the heater. The solution was fed at various rates to the crystalliser to give a range of outlet temperatures and evaporative loads. The air was fed at a constant 500 cu. ft/min., giving a velocity of nearly 100 ft/sec., in the crystalliser column. The following measurements were taken for each run:

solution inlet temperature;
slurry temperature at the thickener;
inlet air wet- and dry-bulb temperatures; and
outlet air wet- and dry-bulb temperatures.

From the change in humidity of the air the evaporation rates were calculated and the log mean driving forces (in atmospheres) estimated from vapour pressure data for humid air and saturated salt solutions. Values of volumetric mass-transfer coefficient, $k_G a$, were then calculated.

In a further series of runs the crystalliser was operated as a simple air humidifier, i.e., hot water was fed in place of the hot salt solution. The purpose of this was to discern the effect of resistance to mass transfer of water molecules by diffusion from the body of the solution to the interface. The results are given in Tables I, II and III.

Discussion of Results

The accurate calculation of the gas film, mass-transfer coefficients is difficult due to the uncertainty of the exact temperature at the interface between liquid and air. On this temperature depends the value of the driving force used in the calculation of the mass-transfer coefficient. In this evaporative crystalliser all the latent heat of vaporisation is supplied from the bulk of the liquid, and, therefore, there must be a temperature gradient from the bulk to the interface. The interfacial temperature is therefore always lower than that of the bulk of the liquid, but in this case there is no way of calculating by how much.

The graphical method[2] of MICKLEY cannot be used with

TABLE I.—The Wetted-wall Column used for Evaporative Crystallisation of Sodium Chloride. Dimensions of Column: 6 ft × 4 in. i.d. Air-flow rate: 2125 lb./hr.

Run No.	TEMPERATURES (°F)						CALCULATED VALUES							Mean Reynolds No.
	Solution into column	Solution out of column	Air into column		Air out of column		Increase in total heat of air (Btu/lb. dry air)	Decrease in sensible heat of solution (Btu/lb. solution)	lb. Solution per lb. dry air	Humidity increase of air (lb./lb. dry air)	Total evaporation (lb. water/hr.)	Log Mean $p_i - p$ (atmos.)	$k_G a$ (lb. moles)/(hr)(cu.ft)(atmos.)	
			Wet bulb	Dry bulb	Wet bulb	Dry bulb								
1	219	134.5	70	82	118.5	120	81	67.5	1.20	0.066	140	0.187	83	190,500
2	205	138	70	82	121	125.5	90	53.6	1.68	0.07	149	0.162	102	191,000
3	208.5	149	70	82	129	132	118	47.7	2.47	0.095	202	0.213	105	193,000
4	214	154.5	70	82	136.5	133.5	135	47.5	2.85	0.110	234	0.252	103	194,000

TABLE II.—The Wetted-wall Evaporative Crystalliser used for Evaporation from Pure Water. Dimensions of Column: 12 ft × 4 in. i.d. Air-flow rate: 2125 lb./hr.

Run No.	TEMPERATURES (°F)						CALCULATED VALUES							Mean Reynolds No.
	Water into column	Water out of column	Air into column		Air out of column		Increase in total heat of air (Btu/lb. dry air)	Decrease in sensible heat of water (Btu/lb. water)	lb. water fed per lb. dry air	Humidity increase of air (lb./lb. dry air)	Total evaporation (lb. water/hr.)	Log mean $p_i - p$ (atmos.)	$k_G a$ (lb. moles)/(hr)(cu.ft)(atmos.)	
			Wet bulb	Dry bulb	Wet bulb	Dry bulb								
5	205	103	70.5	84	101.5	103	40.5	102	0.40	0.032	68	0.1425	24.4	188,000
6	203	117	70.5	84	114	115	68	86	0.79	0.054	115	0.184	34.7	190,500
7	201	124	70.5	84	120	121	86	77	1.12	0.068	144	0.181	44.3	191,500
8	201	137	70.5	82	132	133	133	64	2.08	0.106	225	0.216	58.2	194,500
9	198	146.5	70.5	82	139	140	166	51.5	3.22	0.136	290	0.243	66.3	196,500
10	197	152	70.5	82	142	143	183	45	4.07	0.152	323	0.260	69.0	198,000

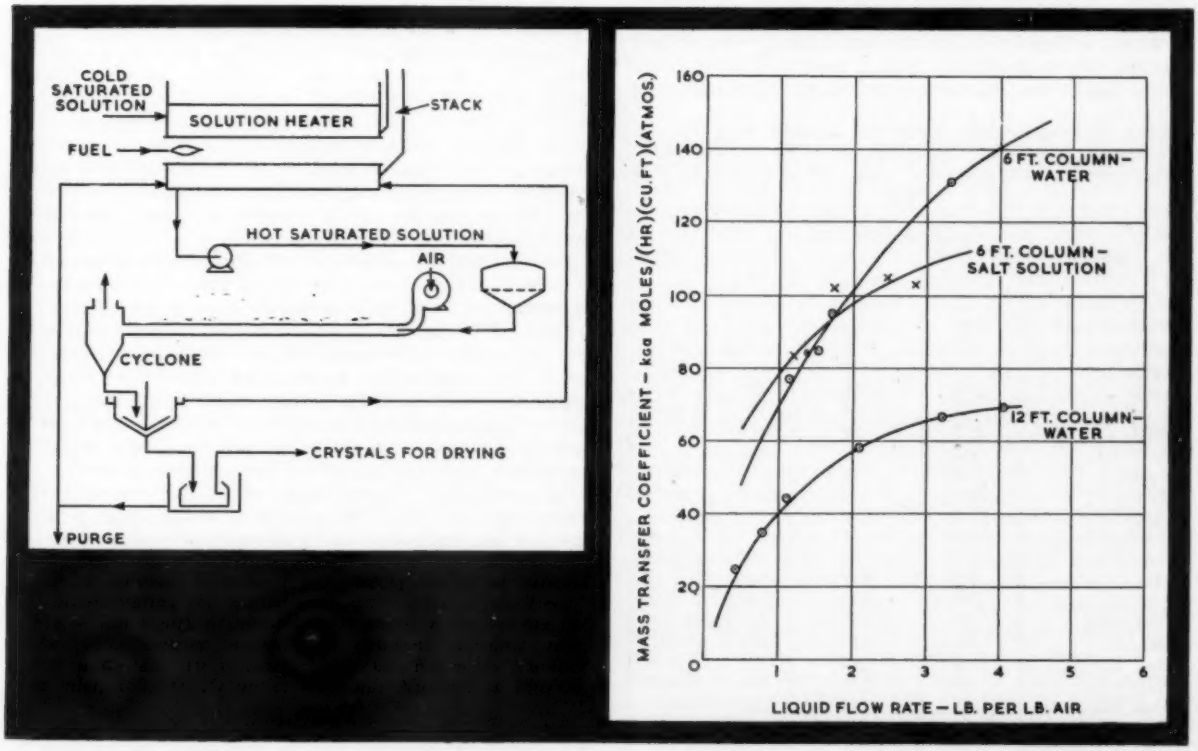


TABLE III.—The Wetted-wall Evaporative Crystalliser used for Evaporation from Pure Water. Dimensions of Column: 6 ft × 4 in. i.d. Air-flow Rate: 2125 lb./hr.

Run No.	TEMPERATURES (°F)						CALCULATED VALUES							Mean Reynolds No.
	Water into column	Water out of column	Air into column		Air out of column		Increase in total heat of air (Btu/lb. dry air)	Decrease in sensible heat of water (Btu/lb. water)	lb. water fed per lb. dry air	Humidity increase of air (lb./lb. dry air)	Total evaporation (lb. water/hr.)	Log mean $p_i - p$ (atmos.)	$k_G a$ (lb. moles)/(hr) (cu.ft) (atmos.)	
			Wet bulb	Dry bulb	Wet bulb	Dry bulb								
11	201	126.5	75	79.5	121.5	123.5	86	74.5	1.16	0.068	144.5	0.199	77.0	191,000
12	203	131.7	75	79.5	126	127.2	95	62.3	1.53	0.082	174	0.218	85.0	192,000
13	198.5	135.0	76	81.0	128.7	130.5	110	63.5	1.73	0.089	189	0.211	95.0	193,000
14	190.5	145	76	81.0	137.5	139.3	152	45.5	3.35	0.121	257	0.208	131.0	195,000

accuracy in this case, due to the closeness with which the air path follows the saturation curve between inlet and outlet conditions. The mass-transfer coefficients in Fig. 4 have been calculated from the experimental results using the maximum possible driving force (i.e., with interfacial and liquid bulk temperatures taken as equal), and they represent the lowest possible coefficients for the gas film, or the actual overall coefficients for the crystalliser.

Calculation of the mass-transfer coefficients by the GILLILAND equation gave values of the order of 150 moles/(hr) (atmos.) (cu. ft) for the conditions of runs 5 to 14. That the experimental overall values are much lower than the gas film coefficients, calculated by GILLILAND'S equation, indicates either that the liquid film offers considerable resistance to latent heat transfer or that the actual interfacial area is less than the column wall area. From observation of the crystalliser in operation, it is clear that, in the case of the 6-ft tube and the higher liquid ratios, the tube wall is completely wetted by the liquid and the low overall mass-transfer coefficients can only be due to the liquid film resistance to heat transfer. With high liquid-air ratios the effective interfacial area can actually exceed the tube wall area, due to wave formation.

With low liquid-air ratios the liquid failed to completely wet the tube wall and this lack of interfacial area, added to the liquid film resistance, accounts for the decrease in mass-transfer coefficient with decrease in liquid-air ratio. This is particularly shown by runs 5 to 10, which cover a wide range of liquid-air ratios.

The higher values of the mass-transfer coefficient obtainable with the 6-ft column than with the 12-ft column means that the first half of a 12-ft column is more effective than the second half. During runs 5 to 10 it was in fact observed that the liquid distribution tended to deteriorate in the second half of the column. This deterioration was due to much of the liquid falling to the bottom of the horizontal column. In spite of this, a longer column has the advantage that it gives the highly supersaturated solution more residence time to relieve the supersaturation, and thereby obviates crystal formation on parts of the cyclone-thickener which follows the crystalliser. Moreover, a horizontal column has certain advantages over a vertical column with downwards flow (which allows some of the liquid to be carried through the column without touching the walls) or a vertical column with upwards flow (which presents difficulties if the air flow stops for any reason).

TABLE IV.—Approximate Theoretical Capacity of a 4-in.-dia. Wetted-wall Evaporative Crystalliser. Based on a 3000 lb./hr. solution flow rate and a solution temperature drop from 212°F to 152°F.

Solute	Crystal yield, lb./hr. anhydrous			Form of Crystals
	Due to cooling	Due to evaporation	Total	
NaCl	66	60	126	Anhyd.
$CuSO_4$	912	115	1027	5 H_2O
$CaCl_2$	570	240	810	2 H_2O
$CuCl_2$	480	161	641	2 H_2O
$Al_2(SO_4)_3$	750	137	887	18 H_2O
$BaCl_2$	313	90	403	2 H_2O
$Ba(NO_3)_2$	352	52	404	Anhyd.
K_2SO_4	150	37	187	Anhyd.
KNO_3	3480	375	3855	Anhyd.
$CH_3.COOK$	1560	625	2185	½ H_2O
$K_2SO_4.Al_2(SO_4)_3$	3600	227	3827	24 H_2O
$MgSO_4$	165	65	230	6 H_2O
$MgCl_2$	300	111	411	6 H_2O
$MnCl_2$	159	175	334	2 H_2O
$(NH_4)_2SO_4$	398	157	555	Anhyd.
NH_4Cl	580	117	697	Anhyd.
Na_3PO_4	1350	180	1530	12 H_2O
Na_2HPO_4	486	155	641	2 H_2O
NaH_2PO_4	1830	372	2202	Anhyd.
$CH_3.COONa$	811	258	1069	Anhyd.

Comparison with other Crystallisers

The wetted-wall evaporative crystalliser has certain similarities to a flash-evaporation crystalliser. In both the latent heat of vaporisation is supplied by the solution, which therefore cools during the evaporation. The cooling, besides causing further crystallisation, may serve a useful purpose if it is desired to suppress the crystallisation of an unwanted impurity having an inverted solubility curve (e.g., calcium sulphate as the impurity in sodium chloride crystallisation).

Both crystallisers effect part of the crystallisation by removal of solvent by evaporation, and part due to the cooling which results from evaporation. They can, therefore, be used for solutes which have very flat solubility curves over the temperature range used, in which case a large part of the crystallisation is due to the evaporation. Some solutes have steep solubility curves for the higher hydrates but very shallow curves for the lower hydrates. Flash or wetted-wall evaporative crystallisations are useful where the crystals are required in these lower hydrated forms.

Flash evaporative crystallisers are of two types: the pressure type, in which the solution is heated under pressure to a temperature above its atmospheric pressure boiling point and then flashed into a vessel at atmospheric pressure; and the vacuum type, in which the solution is heated at atmospheric pressure and flashed into a vacuum vessel. The pressure flash evaporator produces a high-temperature magma and favours the crystallisation of the anhydrous or lower hydrated forms. The vacuum flash evaporator can produce a low-temperature magma favouring the more hydrated forms. The wetted-wall evaporative crystalliser, working over its economical temperature

Humidity, H; Lb.water/Lb.dry air

range, produces a magma temperature in between these two, in the temperature range 110°F to160°F.

The wetted-wall evaporative crystalliser requires no vacuum or pressure equipment, and avoids the difficulty encountered with vacuum-flash evaporation of removal of the slurry from a vessel under vacuum. It does, on the other hand, require a high-capacity, low-head blower.

Flash and wetted-wall evaporation both cool the solution so rapidly that a high degree of supersaturation is reached. This results in a high rate of nucleation and a small crystal size. Due to the high degree of supersaturation, there is a strong tendency for the solution to "cake" on any rough surfaces it touches. It is therefore important to keep the solution away from rough surfaces until the crystal growth has relieved the supersaturation; hence the reason for the column being made of glass pipeline. It was found during the pilot-plant runs that gaskets in the joints of the column provided a rough surface on which a cake of crystals could grow. This trouble was overcome by removing the gaskets, leaving a glass-to-glass joint. It is no disadvantage that the wetted-wall crystalliser has to be made of glass, as glass pipeline can now be obtained in diameters up to 18 in.

Capacity and Cost

The installed cost of a 12 ft × 4-in.-dia. wetted-wall evaporative crystalliser is approximately £150, excluding the tank into which the slurry issues, but including the blower. A suitable air flow for this size of column is 500 cu. ft/min., and the pressure required to pass this air through the column is 8.5 in. w.g. The blower's power consumption under these conditions was found to be 2 kW.

Table IV shows the calculated yield of crystals of various common solutes when the 4-in.-dia. crystalliser is working under the specified typical working conditions. The yield of NaCl was checked on the pilot plant. The yields of the other solutes have been calculated from solubility data, and it is possible that yields of the order of 2000 to 4000 lb. per hour could not be realised in practice, as the slurry might be too thick to handle.

The heat consumption of a plant incorporating the wetted-wall evaporative crystalliser is about 6% higher than that of other evaporative crystallisers when the plant is operated in the tropics where the mean temperature is around 80°F. Operated in a northern climate with a mean temperature of, say, 50°F, the heat consumption would be about 9% higher. The extra heat is absorbed as sensible heat increase of the dry air in passing through the column.

Possible Applications

The wetted-wall evaporative crystalliser is best employed where the following conditions prevail:

(a) small crystals are required, or are not objected to;
(b) the output does not justify the cost of vacuum or pressure equipment and steam-raising plant (if steam is not already available at the site);
(c) the process is one in which the mother liquor from the crystallisation can be returned to the process, enabling the crystalliser to be operated at a fairly high output temperature and economising on air;
(d) the solvent is water or a liquid so cheap in comparison to the value of the solute that it does not have to be recovered; and
(e) the output is insufficient to make recovery of heat from the solvent vapour worth while.

Even where some of the above conditions do not prevail, the wetted-wall crystalliser may have an advantage due to its construction in glass. This is particularly so if the solution is corrosive or contamination of the solution must be avoided.

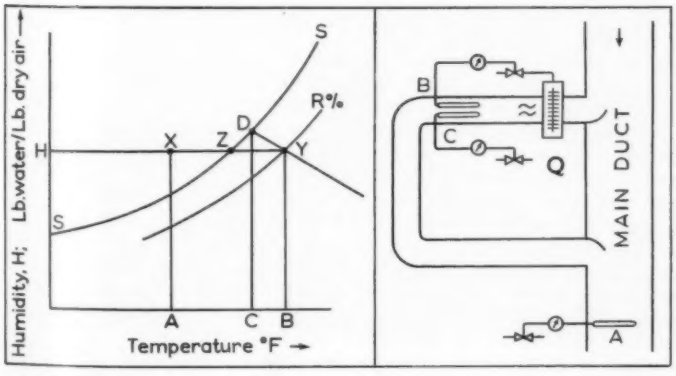
REFERENCES

[1] Gilliland, E. R., and Sherwood, T. K. *Ind. Eng. Chem.*, 1934, **26**, 516-19.
[2] Mickley H. S., *Chem. Eng. Prog.*, 1949, **45**, 739-45.

Control of Air Condition in the Fog Region

by R. H. PURDIE, M.Sc., A.R.C.S., A.R.I.C.

IN certain problems it is necessary to have a mixture of saturated air and water droplets, i.e., a mist, where the amount of free water is controlled. Such an air condition is represented by point *X* in the accompanying skeleton psychrometric chart. This condition is above the saturation line, *S-S*, in the fog area, defined by humidity *H*, dry-bulb temperature *A*. Its wet-bulb temperature is, of course, also *A*. If this air is heated, the change of condition is indicated by a move along the line *XY* at constant humidity; the saturation line is reached at *Z*, at which point the mist disappears. Since exact control at 100% relative humidity is difficult, let the temperature rise further till the air condition is at *Y*, which is described by humidity *H* (value as before), dry-bulb temperature *B*, and wet-bulb temperature *C*. The relative humidity is *R*% on the *RH* line. It should be practical to control air condition at *X*.



From the main stream of air a small fraction is continuously deflected into a side duct (see diagram). The sampling duct contains a heater *Q*, with some mixing baffles downstream from it. Dry-bulb element *A* controls the main heater in the main stream at temperature *A*°. Dry-bulb element *B* controls the secondary heater *Q* at temperature *B*°. Wet-bulb element *C* controls the humidification equipment for the main stream so as to make the wet-bulb temperature in the sampling duct *C*° equivalent to *R*% relative humidity. As a result of this arrangement, the air at dry-bulb *A*° is raised in temperature to *B*° and then its relative humidity can be controlled; the absolute humidity *H* is thereby set, so that the mainstream air is fixed at *H* humidity and *A*° dry bulb, i.e., condition *X*.

It will be noted that since the sampling duct discharges back into the mainstream above the position of thermostat element *A*, the excess heat added by heater *Q* merely substitutes for that amount of extra demand from the main heater. It is clear that this could not be applied to a straightforward adiabatic "washer" type of air-conditioning plant, since its dew point would be at *D*, greater than its dry-bulb temperature *A*. However, it is likely that direct water spraying in air would be the basis of a plant, in which case the mainstream thermostat *A* would control the heaters and the wet-bulb thermostat *C* the spray valve.

THE WORLD'S LARGEST HYDROGEN PEROXIDE PLANT

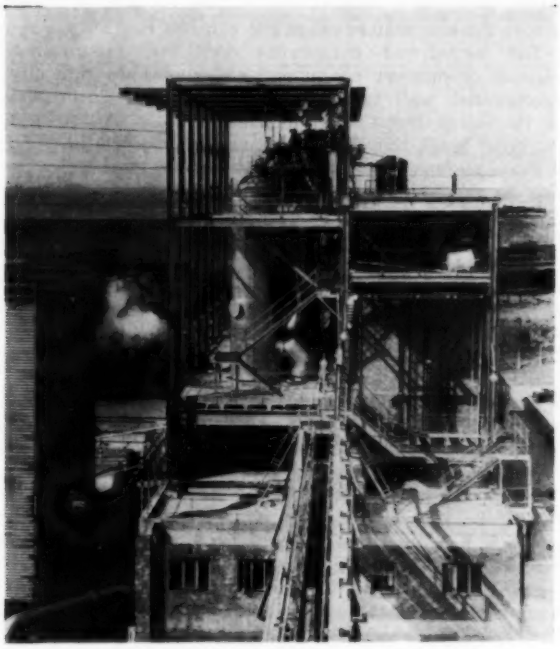
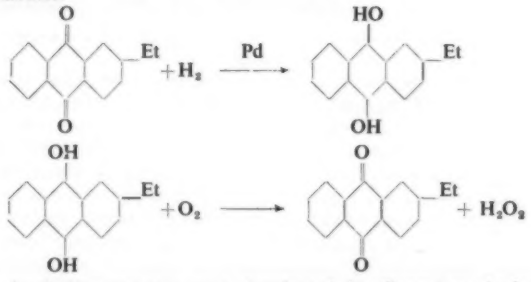


Fig. 1. Side view of the concentration section at the Laporte Baronet works, Warrington.

THE outstanding properties of hydrogen peroxide, its remarkable oxidising powers, its liquid form and high oxygen content presage a bright future for this ideal oxidising agent. The prospects for its broader application should be further improved by the emergence of more economical manufacturing processes. Like most other chemicals, it has had a changing pattern of use and manufacture; at one time its manufacture, with which this article is concerned, was carried out by the barium peroxide process. This was supplanted by electrochemical processes which, in turn, are being overtaken by chemical methods such as the autoxidation processes. In favour of these processes is a much lower power requirement than the electrochemical routes, a lower steam demand, since hydrolysis of a per-compound is not involved, and a favourable effect of scale upon the economics of the processes. The electrochemical process, for example, requires for electrolysis alone some 14 kW per Kg of 100% H_2O_2, whereas with the chemical processes the power consumption is unlikely to be higher than 3 kW per Kg of 100% H_2O_2. Moreover, in the electrochemical processes there is a multiplicity of small units such as cells; as a consequence, increased capacity can only be effected by multiplying these units, not by increasing their size.

At the Laporte Baronet works at Warrington, where both processes are operated side by side, the advance the new process represents is readily appreciated. The new plant erected at a cost of £2½ million, its design aided by an elegant analogue computer study, is an outstanding example of the newer processes. In these processes a hydroquinone type of compound in solution is oxidised to the quinone form with simultaneous formation of hydrogen peroxide. This, in turn, is extracted from the solution of quinone with water to give an aqueous solution of approximately 20% strength. The quinone is recycled and the quinol is regenerated by catalytic reduction in readiness for further reaction.

The process now operated by Laporte at Warrington follows this pattern, the starting material in this case being 2-ethyl anthraquinone. The principal chemical reactions of the process at Warrington are illustrated below. The catalyst is palladium supported upon an inert carrier, but actual details of this in the case of the Laporte process have not so far been disclosed, although the use of an activated alumina catalyst coated with 0.7% of its weight of Pd in Germany has been reported. Other known supports include silica gel, calcium phosphates and certain silicates.



A similar process was developed in Germany during the last war, but a very highly dispersed metallic nickel catalyst was used in order to avoid the use of platinum which was required for the electrochemical process. This type of nickel catalyst has disadvantages, for it is easily deactivated by dissolved oxygen or hydrogen peroxide and is pyrophoric. However, supported nickel catalysts have been developed along with methods for removing the deleterious oxidising agents. Nevertheless, the fact that hydrogen will reduce the metal oxides readily at ambient temperatures is an outstanding advantage of the palladium catalyst. It is, however, not completely selective, since some tetrahydro-anthraquinones and other by-products are formed, the extent of side reactions being influenced by the hydrogenation conditions including the solvent. The latter is of considerable importance and a certain amount of secrecy surrounds the one in use at Warrington, but whatever solvent is used it must be able to keep both the oxidised and reduced compounds in solution and it should not add to the hazards of the process. The first condition

is one reason for the use of mixed solvents, such as benzene-methyl-cyclohexanol. Others which have been noted are primary and secondary nonyl alcohols in admixture with alkylated naphthalenes, di-isobutyl ketone, ketones, chlorinated hydrocarbons and aromatic alcohols and their esters as components of mixtures.

In the Laporte process the hydrogenation is carried out in a pair of vertical 99.5% aluminium vessels of approximately 40 ft height and 10½ ft diameter. An interesting feature of these Argonaut welded vessels is the use of stepped wall thickness varying from 1⅛ in. to 1¼ in. These afford a striking contrast with earlier German plants which used enamelled iron vessels—a feature restricting the size of individual units of plant as well as being very expensive.

The catalyst particles are suspended in the reactants and are retained by a system of filters arranged around the circumference of the vessel. By back-flushing, catalyst retained by the filters can be returned to the vessel for re-use. Since hydrogen in excess is used the unreacted gas is recycled and is joined by a stream of make-up hydrogen supplied from a butane cracking plant.

The filtration system is of special design, and represents an advance over the ceramic candle type of filter used on earlier plants. The larger size of catalyst granules compared with precipitated nickel catalysts is also a distinct improvement, since it allows a greater throughput per unit cross-section of reactor. On the other hand, very coarse nickel catalysts have been used which require agitation to maintain them in suspension. The catalyst employed by Laportes evidently sails conveniently between these two extremes.

As both the regeneration and the following autoxidation stages are exothermic, the materials from the hydrogenators are cooled after leaving the filters. For this purpose water-cooled aluminium shell and tube coolers are provided.

Autoxidation is carried out non-catalytically with air and ethylanthraquinol solution in co-current flow, both being introduced at the base of the oxidation towers, whereas the converted quinone and hydrogen peroxide leave at the top along with the solvent-laden air. The two packed columns used for this stage of the process are approximately 60 ft in height and 12 ft in diameter; 99.5% aluminium is again the material of construction, they are Argonaut welded, and stepped wall thicknesses of ¾ in. to 1⅜ in. are used. Air at 40 psig is supplied from rotary compressors running at 5880 rpm by means of a step-up transmission coupled to a 1480-rpm motor.

The solvent carried away with the air is recovered by adsorption on activated charcoal in two pairs of vessels in series. While one pair is adsorbing, the other is being steamed for recovering the solvents. The hydrogen excess is recycled by means of cast-iron water-ring compressors (Nash Hytors). Their capacity is 400 cfm at 35 psig. Single-stage, double-acting reciprocating compressors supply make-up hydrogen to the plant. These are dry cylinder machines fitted with carbon piston rings and carbon piston-rod glands; their output is 400 cfm at 50 psig.

Separation of the hydrogen peroxide is brought about by extracting with water in a 24-plate extraction column. Deionised water from a mixed-bed unit is introduced near the top of the column and the solvent and peroxide enter at the bottom. The peroxide-free solvent is withdrawn from the top and collected in storage tanks in readiness for regeneration. The aqueous extract of about 20% strength of peroxide is pumped away from the base to a washing stage for the removal of organic matter, and thence to aluminium storage tanks. The quality of the product is examined at this stage.

Fig. 2. Part of Laporte's control panel at Warrington.

Hydrogen Peroxide Extraction

The extractors, of which there are three in parallel, are 80 ft in height and 9 ft in diameter. Stepped-wall thicknesses are used as with the other Argonaut welded vessels. But apart from their mechanical design, the extraction columns are an interesting chemical engineering achievement; when the design was contemplated data on the system, solvent-water-peroxide, required for estimating the number of contacting stages were not in existence. Undoubtedly, the design represents a great deal of original work in the field of liquid-liquid extraction.

Two of these vessels are constructed from 99.5% aluminium, while the remaining one is fabricated from N4 alloy (1.8%-2.7% Mg). In the case of the 99.5% aluminium vessels, the wall thicknesses vary from ¾ in. at the top to 1¼ in. at the bottom, the pressures at top and bottom being respectively 17 psig and 35 psig. The N4 alloy tower has a thinner wall, the thickness varying from ¼ in. at the top to ½ in. at the bottom. The operating temperature is in the range 60-70°F.

While few details have so far been released about the method of concentrating the aqueous solution, it seems likely that the method employed follows the lines of an earlier Laporte development. In the electrolysis of ammonium sulphate the hydrogen peroxide vapour formed by distilling the products of persulphate hydrolysis is recovered by a three-stage, vacuum-condensation operation. This yields a 30-35% H_2O_2 solution which can be further concentrated to the 90% level in a two-stage vacuum distillation unit. One of the difficulties with this final stage has been the accumulating of impurities in the first reboiler, for when these reach a concentration of 50 g./l. the contents of this vessel must be discharged. This means interrupting the peroxide distillation every 4 to 5 days.

Laporte's method overcame this difficulty. The 30-35% peroxide solution, its *pH* adjusted to 3 to 5, is passed through a steam-heated climbing film evaporator connected to a vapour-liquid separator. The vapour passes to a ceramic, Raschig-ring-packed stoneware-distillation column and the liquid is recycled to the evaporator bottom. The conditions of distillation are adjusted to provide a solution of 70% strength at the bottom of the column. This solution enters a second climbing film evaporator and passes to a separator with recycle of liquid as before, and with vapour feed to a second distillation column. This yields a 90% solution of peroxide. The vacuum maintained is about 40-50 mm Hg. The impurities which collect at the first evaporator can be bled from the vessel without interrupting the concentration of hydrogen peroxide. What has

been disclosed concerning this section of the plant is the use of a distillation column of 99.5% aluminium fitted with West trays, which are especially suitable for operating under vacuum. This is a departure from previous practice, which relied upon stoneware-packed columns.

Since the vapours and liquids encountered in the plant are highly inflammable, wide use is made of pneumatic controllers. Flow, for example, is metered by differential pressure transmitters using orifice plates as the primary elements, and is controlled by valves closely connected to three-term, force-balance-type controllers. Pressure in some of the vessels is measured by differential pressure transmitters; levels are controlled by displacer-type level controllers fitted with two separate pneumatic systems—one for actual control of level, the other for transmitting the level measurement to ribbon-type indicators situated in the control room. Electronic Wheatstone Bridge instruments are used in conjunction with platinum resistance thermometer elements for temperature measurement. Gas-phase oxygen concentration, a variable of prime importance in the operation of the plant, is measured by magnetic wind type instruments with potentiometric recorders. Seven of these analysers are installed at different points of the plant and their ranges vary from 0 to 20% oxygen in nitrogen to 0 to 3% oxygen in hydrogen. The main tank contents are measured by standpipe air-reaction instruments, although a few force-balance transmitters in conjunction with ribbon indicators are used for this purpose also.

Besides instruments and controllers, alarms are provided for tank levels, interface levels, low pressures and gas analyses. Interface-level alarms depend upon conductivity probes—the heavier phase is conducting—and float switches operate level alarms. Pressurised instrument cases are provided where intrinsically safe circuits have not proved practicable. Valve positioners are fitted to all valves above 2 in. in base, and quick-acting pneumatically-operated three-way valves required in certain parts of the plant are actuated by power cylinders fitted with pilot valves.

The alarms and recording instruments are mounted upon an instrument panel in the main control room. The graphic part of the panel (Fig. 2) is concerned with the hydrogen, autoxidation and extraction stages of the process. In addition there are two other sections of the panel, one for the alarms and another for temperatures, tank contents and gas analyses. The combination of the two types of panel is noteworthy.

An interesting safety measure is the use of carbon dioxide, recovered from the butane cracking plant, as a purge gas for the autoxidation process. It is also used as an inert atmosphere in storage tanks containing inflammable liquids.

Computer Aided Design

A striking thing about the design history of this plant was the method used to test the full-scale design in early stages of the project. In the study carried out by a joint E.M.I. Laporte team, an analogue computer was used to simulate the important aspects of the plant performance. Not the least noteworthy feature of this work was the successful co-operation of engineers representing two quite distinct technologies, the electronic engineer on the one hand and the chemical engineer on the other. The correctness of the conclusions arising from this joint venture were confirmed when the plant came into actual operation, an achievement due in no small measure to the guidance provided by the computer experts in assisting the chemical engineers to express the behaviour of various sectors of the process in mathematical forms suitable for computer treatment.

A number of points in the design had to be decided. In the first place the adequacy of the vessels for all the material changes in flow rates of process fluids had to be proven. The possibility of sustained hunting through interaction between various vessels and controllers had to be eliminated. The optimum settings of controllers themselves were required; finally those parts of the process particularly prone to instability had to be found. The principal variable to be controlled at various parts of the plant was liquid flow, and the performance of the control loops for regulating this variable had to be determined. More than thirty equations, representing the situation at different points, were derived. These took into account the capacities of vessels, pressure losses through equipment, and the response characteristics of the automatic controllers themselves. The kinetics of the hydrogenation and extraction processes did not, however, require treatment in this study, which was concerned also with the transport lags and damping effects which occurred at each plate of the extraction column.

The computer was connected to various instruments measuring flows, pressures and liquid levels in many parts of the plant so that when a disturbance was created at any of the points under examination its effect upon the process could be observed. The computer was able to compress the time factor by a ratio of 60 to 1 in this work. In addition to the information on controller settings, the computer tests did, in fact, reveal that the likelihood of sustained hunting was remote, that the vessels were properly sized to take care of all foreseeable fluctuations in throughput, and that oscillations introduced by hunting of the gas phase controllers were of a frequency unlikely to cause the plant as a whole to hunt.

Investigation Costs Moderate

The very modest sum of £3000 for this investigation, compared with a total installed instrumentation cost of £75,000 and the outlay of £2½ million for the entire plant, should encourage other firms in the processing field to consider the use of computer methods for the evolution of integrated plant designs.

Turning to the ancillary equipment, such as valves and pumps, the solvent is circulated by centrifugals constructed of 18/8 stainless steel whereas aluminium (99.5% Al) self-priming centrifugals handle hydrogen peroxide solutions. Both groups of pumps are fitted with mechanical shaft seals. Valves in the solution pipelines are of stainless steel and employ a special packing which not only requires very little maintenance but also minimises solvent losses. Where suspensions of catalyst are involved, "Y" valves are provided fitted with seat-wiping mechanisms.

For the process, credit is due to the Laporte Research and Development Departments at Luton; for the plant design, instrumentation, and construction, the Group Engineering Construction Department of Laporte Industries in London. The aluminium processing vessels, which in size, at least, are a unique feature of the plant, are products of The A.P.V. Co. Ltd., who were the main contractors for the plant along with Matthew Hall & Co. Ltd. Aluminium storage tanks were manufactured by F. Braby. The stainless-steel centrifugal pumps were supplied by Hayward Tyler and the aluminium pumps by British LaBour. The high-speed rotary air compressors were made by James Howden & Co. Ltd., of Glasgow, and hydrogen make-up compressors by Broome & Wade. The recycle compressors were supplied by the Nash Engineering Co. The hydrogen plant is a Power Gas Corporation product, while the solvent recovery unit was designed by British Ceca Ltd. The special stainless-steel valves with the seat wiping device were manufactured by Joshua Hindle Ltd.

Growing List of Unit Operations

A NUMBER of unique developments have been made in the industrial processing field, and some of these may seem almost bizarre to chemical engineers trained in the classical series of unit operations. This progress is not surprising, since new materials become available almost daily, specifications continue to tighten and production costs inexorably rise unless established methods are improved. Eventually, competition, that great catalyst of change, causes an existing technique (sometimes from an unrelated field) to be adopted, or a new one is invented, thus increasing the growing list of unit operations.

Consider, for example, a new granulating method, the "Compacting Process", developed on a large scale by the Allis-Chalmers organisation. This is an operation for producing uniformly-sized granules from amorphous or fine crystalline materials, and is based on an apparent corollary of RITTINGER's Law. Fine material is fed to the nip of a heavy twin-roll mill and emerges as a dense sheet, which is subsequently reduced to granular size in a two-high roll crusher. Oversize is recycled to the granulator feed and undersize is sent to the compactor for reprocessing. At present, the compactor is made with bearing capacities of 9000, 80,000 and 150,000 lb., with corresponding roll sizes of 10 in. diameter × 42 in., 20 in. diameter × 20 in. and 18 in. diameter with 16-in., 20-in. and 24-in. faces. Horsepower ranges from 50 to 100 and the largest machine can apply a working force as high as 18,750 lb. per linear in.

The capacity of a compacting mill depends on the material being processed and, to a large degree, the power input. A rate between six and ten tons per hour can be anticipated in many instances on the large machine. The price for a complete installation, including one 18 in. × 24 in. compactor, two 10 in. × 24 in. granulating mills, together with elevators, screens and motors, is in the region of $100,000. Typical product sizes are in the 6 to 40 mesh range and recycle percentages may be 20 to 30, according to the nature of the material. It is claimed that both installed costs and operating costs compare very favourably with those of conventional granulating systems.

An unusual type of grinding and dispersion mill has been developed by the Du Pont company and is available under licence. This is known as a "sand grinder" and is now used increasingly for the fine reduction of crystalline materials, dyes and pigments, as well as the preparation of dispersions. The mill consists of several horizontal steel discs revolving on a vertical shaft at about 1000 rpm, to give a peripheral velocity of some 2000 ft per min. A perforated metal or wire cage surrounds the disc assembly to retain the grinding medium between the discs. A satisfactory medium has been found to be silica sand in the 20 to 30 mesh range. The mill-body is a water-jacketed steel cylinder and a 16-gal. capacity mill absorbs about 20 hp when producing 170 to 200 gal. per hr of product. The grinding action arises from large velocity differences between adjacent layers and particles of sand, induced by turbulence in the liquid spinning between the revolving discs. Fine material between two sand particles is subjected to high compressive and shear forces, which cause rapid attrition and dispersion, to yield particle sizes as low as 0.2 to 30 microns. Substantial savings in power and labour are reported to be achieved by the use of this mill, which is designed for continuous operation, when compared with older batch methods. However, present models are not suitable for grinding very large crystals and agglomerates, or for handling thick pastes and mixtures. Maintenance and wear of the "sand grinder" are said to be insignificant.

A good deal of interest was aroused some time ago by the availability of vapour-phase selective adsorbents, or "molecular sieves", from the Linde company. These agents are dehydrated, crystalline alumino-silicates containing a vast network of inter-crystalline voids in which selective adsorption can occur. Selection can be on a quantitative basis, according to molecular size, or in a qualitative manner, depending on such factors as unsaturation and polarity. Naturally, it has not taken the chemical industry very long to find large-scale uses for such materials, especially as they are in the $1 to $2 per lb. price range, and a variety of applications has already been disclosed. One important function is the scavenging of residual moisture in process gases after dehydration in conventional silica gel or alumina driers. An example quoted is the reduction of moisture from 0.15 ppm to 0.05 ppm in natural gas, following dehydration in a silica drying tower. The ratio of sieve to desiccant used is in the 1:20 range by weight. Another application is the dual removal of carbon dioxide and moisture from ethylene. CO_2 is reduced from about 4000 ppm to under 1 ppm, and a final dewpoint below −100°F is simultaneously achieved. The property of selective adsorption as regards sulphur offers great commercial possibilities in view of the increasing emphasis on sour gas treatment in Europe and other parts of the world. A Texas installation has been designed to reduce H_2S in natural gas from 73 grains per 100 cu. ft to below 0.03 grains per 100 cu. ft and to achieve dewpoints below −100°F by using a single-pass, two-bed sieve unit. Compared to a conventional mono-ethylamine scrubbing system, operating costs are anticipated to be reduced by some 50% for an equivalent initial investment.

Making strong claims to being a new type of operation is tangential screening, originally developed by the Dutch State Mines, and brought to industrial maturity by the Dorr-Oliver organisation. The D.S.M. screen is an ingenious, low-cost, non-mechanical solids classifier in the 8 to 100 mesh range with a very high capacity. It consists of a wedge-bar screen curved like a chute and mounted in a stationary housing, with provisions for introducing the feed and withdrawing the undersize and oversize products. Slurry is fed by gravity tangentially on the upper surface of the screen and flows down the inner concave side. Partially dewatered undersize passes through the bars and collects in the screen box, while oversize material slides over the screen surface and is discharged at the base. Size separation is controlled solely by the distance between the wedge bars. Separation is unique in that the largest undersize particles measure about one-half of the gap between the bars. Typical capacities range from 200 U.S. gal. per min. per ft width for 48 mesh screened material to 500 U.S. gallons on the same basis when producing an 8-mesh undersize. The screen is essentially non-blinding and, at present, is available in single units up to 4 ft wide. Current applications include scalping oversize and tramp material, screening magnetite in heavy media separation plants, sizing feeds in metallurgical processes and classifying mill slurries in closed-circuit grinding operations.

66.01: 657.474

COST CONTROL IN CHEMICAL PLANT*

I. Large Plants and Few Products

by F. A. Richmond (Courtaulds Ltd)

THIS paper relates to the manufacture of large outputs of a small number of products—the manufacture of sulphuric acid and carbon disulphide. The value of the plant is £1,750,000, and the personnel concerned is about 410 hourly paid and 120 staff.

Establishment of Standards of Reference

Costs. For large outputs of a small number of products, large plants are almost sure to be used, and these, to be efficient, are almost sure to be continuous. In order to control the losses and yields of raw materials, correct measurement and control are imperative, and instrumentation therefore plays a large part.

Services (steam, water, etc., per unit of product); production wages; and engineering maintenance are covered by systems of budgetary control and standard costs.

"Standard costs" is a method of comparing actual costs with standard ones as set up by a team, which will be described. Standard costs has the advantage that a norm is used, against which to compare the actual costs of producing the product as they occur. This is better than comparing with historical costs because first, these vary from month to month, and second, because there is no basis for historical costs except history, whereas with standard costs they are what are deemed to be the best possible practice. At the author's works, the standard costs were set up by a team consisting of a chemical engineer and an accountant. They examined the flow sheets and set out the mass and material balances, and from that costed the production of the final product. There are, however, further costs which play a part, namely repairs and maintenance costs, and the standard for these is set up at the same time as the annual budget (see p. 93). Fig. 1 is a standard cost sheet for the production of the two main items manufactured. You will note that the period is so-many weeks, the number being shown blank. This is because we work in periods of four or five weeks, and not in calendar months. A production is then shown in the "actual" production in tons for the period, the "budgeted" or "standard" tons for the period, and the increase or decrease—that is, whether the achievement is above or below the budgeted amount. Below are a series of columns in which the main headings of the costs of production are shown. These headings are down the left hand side of the sheet, and are self-explanatory, and the columns used for the figures are "actual"—which is the actual cost for the period, "budgeted and standard" —which is the standard cost, the "total variance"—which is the difference between the standard cost and the actual cost. This total variance is then broken down into four other variances, which again come under two headings named "controllable" and "not controllable". The "not controllable" are those which are outside the control of the works manager, namely cost of raw materials, cost of wages, etc. Under the "not controllable" heading is a volume variance, which represents a change in policy; that is, if the works manager is ordered to make a different amount from the budgeted amount. The "price rate" is a question of the costs of raw materials. This can be raw materials for the product and also for the services—for instance a change in the price of coal for steam. Under the "controllable" items, again is a volume variance, which represents a difference in volume from the standard amount, and the other one is "efficiency", which is entirely due to running the plant efficiently or not.

Every item on this standard cost sheet is shown as money in cost per ton of the manufactured product. There are no items such as "lb. of steam per ton of product", "man hours per ton of product", "therms of gas used per ton of product". It is a definite policy to reduce everything to terms of pounds, shillings and pence per ton of product. This is done because, first, the accountants do not have to break off their calculations to produce other figures such as "lb. steam per ton of product". Second, it brings home to the people who use the standard cost sheets the actual amount of money that they can save by improvements in the efficiency of the plants. In other words, it makes for cost-conscious personnel.

The sums of the costs at the bottom of the page show the factory cost of production, but the total direct charges and the apportioned charges (the overhead costs) are shown separately. Those in charge of plant production are not interested in overheads. Therefore, for standard cost sheets sent down to plant superintendent level, the sheets are filled in down to the total direct charges, whereas the copies of the sheet sent down to the works manager and beyond have the apportioned charges shown, and show the total factory cost of production—that is, the cost of having the product ready to ship from the factory.

As already mentioned, some of the items on the standard cost sheet have to have their standard set annually when preparing the budget. At the beginning of every financial year a "budget of production" is produced in consultation with the sales department, and this is used to arrive at a budgetary cost of production of the items made in the factory. The raw material costs are budgeted, and the production is budgeted. The standard costs for the budgeted production are then worked out, with the engineers being given the opportunity of estimating their repair and maintenance costs. From this budget appear the standard costs for the year. These are not disturbed unless at the half-year they are found to be greatly out, such as due to big alterations in the production programme. The policy is, however, not to change the standards for the whole of the financial year. It is apparent, therefore, that some of the standard costs are set up by study of the exact operation of the plant, and these are then used to get the exact production cost for the budgeted amount. Other items are estimated by those concerned. From these two sources the standard costs are built up and are used for the year.

Plant Usage. (Per cent used of rated capacity.) This is a difficult decision to make. It is the production manager's decision, assisted by Gantt charts or any other aids he may have. Statistics can be used in assisting to reach the correct decision, and an operational research department can be very useful in this field. Stocks of finished and raw materials are useful for evening out hills and valleys in the demand curve, particularly where this is seasonal

* Based on papers read to a symposium held by the North-western Branch of the Institution of Chemical Engineers at Manchester during 1958.

COURTAULDS LIMITED (CHEMICALS DIVISION) UNIT.....

COST OF PRODUCTION FOR THE WEEKS PERIOD ENDED

PRODUCT.....

PRODUCTION	Tons	Tons		Tons	Tons
				INCREASE/(DECREASE)	
	ACTUAL	BUDGETED & STANDARD	TOTAL VARIANCE	DETAILS OF VARIANCE	
				NOT CONTROLLABLE	CONTROLLABLE
	Cost Per Ton	Cost Per Ton		Volume	Price /Rate	Volume	Efficiency
	£. s. d.	£. s. d.	s. d.	s. d.	s. d.	s. d.	s. d.
Raw Materials							
Sulphur/Pyrites							
Charcoal/Briquettes							
Other							
Net Credits for							
Handling Raw Materials							
Manfg. Wages & Salaries							
Manufacturing Wages							
Manufacturing Salaries							
Works Services Direct							
Power, Light, Heat & Water							
Other Services							
Less Credit for Steam							
Repairs & Maint. Direct							
Plant							
Buildings							
Depreciation Direct							
TOTAL DIRECT CHARGES							
Apportioned Charges							
Holiday Pay & Allowances							
Power, Light, Heat & Water							
Other Works Services							
Other Repairs & Maint.							
Rents, Rates & Insurances							
Other Depreciation							
General Trading Expenses							
TOTAL APPORTIONED CHARGES							
FACTORY COST OF PRODUCTION							

Fig. 1. Example of a standard cost sheet.

and predictable. Decisions regarding the use of plant cannot be made entirely on the cold facts presented, as personnel redundancy must be taken into consideration, and if it is shown by statistics that the plant ought in the interests of efficiency to be shut down and started up again in a short time, the manager is faced with either having to stand off personnel or keep them on the payroll doing inferior work in order to have the team ready to start the plant up again. With considerations such as this, it is often better to keep on the labour force, particularly on a complicated plant, and run two plants at half output instead of one at full. The long term policy must be set by management, and carried out by production management.

Quality. For raw materials first, the specification must be set. This must be rigid enough to ensure the quality necessary for producing the end-product of the quality desired. If it is too rigid it may put the price of raw materials up, and if it is too loose it may be too difficult to make the end-product of the requisite quality. Having set the specification, it is necessary to sample the material carefully and analyse it.

With the finished and intermediate products again, a specification must be set, and the sampling system must be a good one. The samples can be tested (a) by plant operators, (b) by shift chemists, and (c) for more highly developed analyses, in the analytical laboratory.

Collecting and Presenting Data

Costs. Returns for raw materials and outgoing finished products are made by the production department or by the traffic department for raw materials over the main weighbridges. The returns go to the accounts department for costing and producing information required by various departments. Standard cost sheets are produced every four or five weeks, and, as already explained, are given down to plant superintendent level, showing total direct charges only, and to works manager level, showing also the overheads.

Returns on plant usage are sent by the production department to the accountants department and to management weekly, and meter readings for services are taken by engineers weekly, and returns sent to the accountants department. The accountants allocate production wages from actual wages entries on clock cards.

A bonus system for maintenance tradesmen is in operation, and every job has a card made out for it. The tradesman clocks-on on his card when he starts the job, and clocks off when he has completed it. The amount of hours he saves against those he has been allowed are credited to him for bonus purposes. As each job has a separate card, these cards are very easily used for cost allocation purposes by the accounts department. In practice, the bonus is averaged for the whole week, and so is the overtime, so that a man-hour is worth so much money in any particular week. The job cards are collected under their plant headings, and the total number of man hours for that week produces the maintenance costs for that plant for that particular week. This does not give exact costs, but is a short cut which is well worth while, and the costs so produced are accurate enough for management purposes.

If the results of the analyses (see above) show that the quality of a product, whether raw, intermediate or finished, is up to standard, no action is taken. If the product is below standard, then an examination takes place immediately.

Role of Production Management

There is a feed back monthly of standard costs and consumptions to the persons who formed the budgets and standards, and down to supervisor level. If the costs are going well, that naturally earns praise from the management; if it is not so good, the reasons are found out by investigation and the necessary reprimand to the persons concerned is given, or action is taken to offset any rise in costs by plant improvement or by improved techniques, instruction or discipline. It will be seen that as the organisation responsible for collecting the data is the production department for production items, the engineers for services, and the accountants for producing the figures and returning them to the departments concerned, there is no question of a relationship with the organisation responsible for producing and presenting the data, and why this should be is not understood by the author.

Stocks of raw materials and finished products are budgeted for, and the budget is revised, if necessary, if trade suddenly alters. The budget is, like all the others already mentioned, made annually and revised, if necessary, after six months. The budget for sales is made by the sales department. Stocks of finished products and raw materials can be allowed to fluctuate, to iron out fluctuations in delivery of raw materials or finished products. The idea is to keep the plant running on a constant load.

Cost reductions already covered earlier are controlled by budget and standard costs. The aim is to obtain cost-conscious supervisors. The best cost reductions come from a good development team searching all the time for better ways of running the plant, at the manager's disposal, and from research into new processes carried out by a research team, which in a large firm is usually organised centrally Method study is useful to the management, to better detailed working on the plants of both production and maintenance personnel.

2. Plant Producing Many Products

by F. P. Stainthorpe, Ph.D. (The Clayton Aniline Co. Ltd.)

IT is the purpose of this paper to illustrate how modern costing techniques are used in a fairly large factory when the majority of the products made in a works are required in relatively small tonnages. The factors which influence the method of costing are:

1. The diversity of the products—nearly 1,000 different products, including intermediates, are made.
2. The range in rate of production—from over 100 tons a week for some materials to less than 5 tons a year for others.
3. The manufacture of most of the products from intermediates within the works.
4. Production being mainly batchwise.
5. The ability of the plant units to be combined in various ways to produce different but usually related products, and the manufacture of any one product being generally exclusive even though the full capacity of all the plant items is not exploited.

For management to be efficient there is an enormous amount of information to be assembled and collated, moreover the analysis of this data should be completed rapidly so that control can be maintained. We have introduced a standard costing system whereby all the products are given a standard cost, and a regular comparison of actual costs with those expected from the standard is made, so that departures can be detected and, if necessary, corrective action can be taken. Fortunately, most of the accounting can be mechanised and we employ a Hollerith system, which involves the use of card punchers, checkers, collators and tabulators, together with a 550 punch card calculator to do the large amount of arithmetic involved in operating accounting process. The standards having once been set up remain fixed for one year and are then adjusted in the light of experience and for process changes where necessary. The first stage is to set up a standard cost for each product based on: (1) Material costs; (2) Direct manufacturing costs—services, labour, maintenance, depreciation; and (3) Overheads.

Materials

To establish material consumption standards, the latest process as operated in the works is considered, and the consumption of all materials per 100 lb. of yield of product is established. The figures taken are not the ideal figures but represent the reasonable usage for a particular product when manufactured under the normal condition for normal runs, so that losses which arise from handling, evaporation, cleaning out of plant when changing production, etc., are included in the standard consumption.

The yield per batch is expressed as a straight weight per cent yield, based on the main starting product, which is the most important (or the most expensive) material used in the process. For colours the practice is to express the yield in terms of 100% type so that the effect of strength adjustments to suit different demands does not affect the standard cost or the subsequent comparisons.

Direct Manufacturing Costs

Where it is possible to measure directly the consumption of services, labour, etc., for the production of a particular product over a reasonable period, then an accurate standard based on these measured figures is derived. Usually, however, it would be impracticable to carry out these measurements and a method of estimating the requirements has to be used together with a method of allocating losses, etc., and also checking the overall balance. The actual method of estimation varies according to the class of manufacturing costs so these will be dealt with separately (see Figs. 2a, 2b, 2c and 2d).

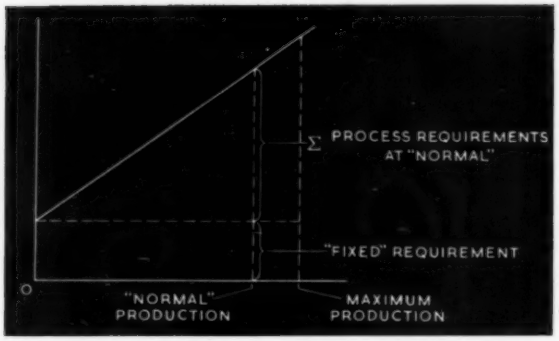


Fig. 2a. How service requirements are determined.

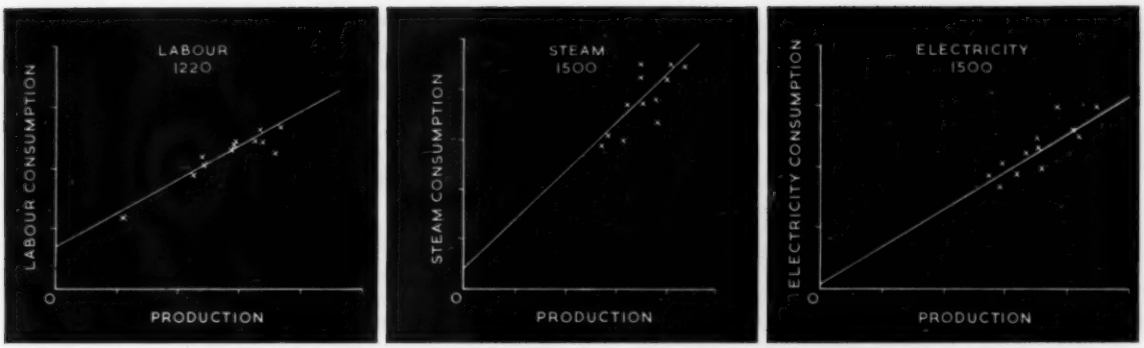
(1) *Services.* Services include steam, water, electricity, air, gas, fuel oil, coke, etc., and, except for the latter two, which are measured on to each job, the services are metered at the point of entry into each building. The principle of the method of estimating requirements is the same for all these services, and steam can be taken as an example.

The standard process requirements are built up of two parts—(*a*) Those which arise directly from the manufacturing operations, and which are called the "principal requirements"; and (*b*) Those which arise from incidental operations and not necessarily every batch, such as cleaning out vessels before and after a run on any one product. These are called the "secondary requirements".

The principal requirements are estimated by reading through the process and calculating the steam used at each stage after making simplifying assumptions to keep the task within practical bounds. Thus, all charges are converted to water equivalent by assuming a specific heat of 0.5 for organic liquids, except chlor-compounds which are taken at 0.3, and similar approximations are made for solids. A table (1) giving steam requirements for raising given weights of water through 10° intervals from 15°C, which is taken as datum, is used to arrive at the relevant figures for raising the charge to the reaction temperature. Steam is also required of course to raise the vessel to the reaction temperature. From a set of graphs relating the water equivalence of various standard types of vessel to their nominal capacity, another figure can be obtained which is used with the same steam-consumption table to arrive at an estimate of the steam required to raise the vessel to the operating temperature (see Fig. 3).

Heat losses are allowed for by taking 10% of the steam required to raise a vessel to its operating temperature per hour on temperature. Losses by evaporation from the surface of open or well-draughted vessels are estimated using a table (2) relating loss each hour to the diameter of the vessel and the temperature of the contents. For certain operations such as drying, a typical figure for the steam consumption per pound of water evaporated in each type of drier has been obtained by measurement and is applied to all products dried in that type of machine. Estimates for special requirements follow conventional practice. The sum total of all these primary process requirements is found for the manufacture of one batch of material.

The secondary requirements such as steam required for operations like "boiling out" are estimated with the same procedure as above and are then reduced to batch consumption by dividing the figure obtained by the number of batches in a normal run on this product. This conception of a normal run is important from this point of view and is an estimate of the typical lengths of runs made on this product. Clearly it does not pay to clean out a plant and start a campaign which consists of only two or three



Figs. 2b, 2c and 2d. Examples of plotting labour and services against production.

batches; we prefer to run the plant for probably a minimum of eight to ten batches, and of course, many more are desirable. However, there is an upper limit imposed by the stock position, and the need for avoiding the carrying of excessive stock and occupying warehouse space for unnecessary lengths of time.

The sum of the principal and secondary requirements is the "standard process requirement" and to this has to be allocated a share of the losses which are known to occur. These steam losses, which are known as "fixed requirements", vary according to the type of plant and building but can be estimated fairly reliably by using a Willan's-line technique. In any one building the output varies according to demand, and the steam consumption according to the product being made, but the range of variation in pounds of steam per pound of product is small for a particular plant, so that by taking quarterly records over three years of the total weight output from the building and the measured steam input, we can correlate the steam consumption with the production. The line of best fit through the rather scattered points obtained can be extrapolated to zero production and thus gives an estimate for the fixed requirement. In order to allocate this fixed requirement to each product it is necessary to assume that normal production is a certain percentage, say 85%, of the maximum capacity of the building, the fraction shown as:

$$\frac{\text{Fixed steam}}{\text{Total steam at 85\% capacity} - \text{fixed steam}}$$

then gives the correction to be added to the process requirement. The corrected figure is taken as the standard consumption. A similar technique has been used for the estimation of standard consumptions of electricity. In most cases the fixed consumption of electricity is a very much smaller proportion than it is with steam, but we did come across one or two cases of an exceptionally high fixed consumption, which called for immediate attention. Estimates have also been made of the consumption of water, air, for purposes of allocating charges but the costs of these services are secondary and do not normally appear directly in the costing. They are charged by making an

TABLE 1—Pounds of Steam Required to Raise a Given Weight of Water from 15°C to T° C

← L.P. H.P. →

T / W lb.	25	35	45	55	65	75	85	95	105	115	125	135	145	155	165	175	185
100	2	4	7	9	11	13	15	17	20	22	24	26	28	32	34	36	40
200	4	9	13	17	22	26	30	35	39	43	48	52	56	64	68	73	77
300	7	13	20	26	33	39	46	52	60	65	72	78	85	95	102	110	115
400	9	17	26	35	43	52	60	70	78	87	95	104	113	127	136	145	154
500	11	22	33	43	54	65	76	87	98	108	119	130	141	159	170	182	192
600	13	26	39	52	65	78	91	104	117	130	143	156	169	190	204	218	232
700	15	30	46	61	76	91	106	121	136	151	167	182	197	222	238	254	270
800	17	35	52	69	87	104	121	139	156	174	190	208	225	254	272	290	308
900	20	39	58	78	98	117	137	156	176	195	215	234	254	286	306	327	347
1000	22	43	65	87	108	130	152	174	195	217	238	260	282	318	340	363	386
2000	43	86	130	174	217	260	304	347	361	434	477	520	564	636	681	726	772
3000	65	130	195	260	325	390	456	521	586	651	716	781	846	953	1022	1090	1158
4000	87	174	260	347	434	520	608	694	781	868	955	1042	1128	1271	1362	1453	1543
5000	109	217	326	434	543	651	760	868	977	1085	1194	1302	1411	1589	1703	1816	1929

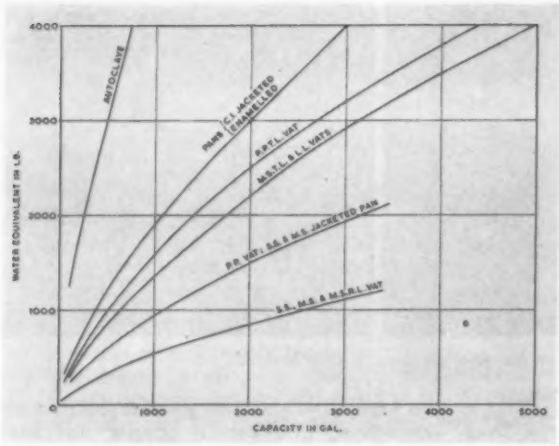


Fig. 3. Graph relating vessel water equivalence to nominal capacity.

TABLE 2—Heat Loss from the Surface of a Vat, Diameter 'D', at T°C Pounds of Steam per Hour

T / ft. in.	50	60	70	75	80	85	90	95	98
3 0	5	9	14	17	22	26	32	38	43
4 0	9	16	24	30	39	46	57	68	76
4 6	11	20	31	38	49	58	72	86	96
5 0	14	24	37	46	60	72	88	105	118
5 6	17	30	46	57	73	87	108	128	144
6 0	20	35	54	67	87	104	129	153	171
6 6	24	42	64	79	102	122	151	179	201
7 0	28	48	74	92	118	141	175	208	233
7 6	32	55	85	105	135	162	201	238	267
8 0	36	63	97	120	154	185	229	271	304

adjustment to the steam prices. Again, abnormal consumption figures were revealed when making the standards and recognition of the exceptional figures led to remedial action being taken. Gas, coke and fuel oil have all been measured and standards set up for each product.

The use of the simplified method of estimating service requirements means that the individual plant chemists can make the estimates. This in turn means that the calculating load is distributed. Moreover, it tends to bring home to each chemist the sources of large steam consumption, etc., which he may not be fully conscious of beforehand. It has been found that, where carried out carefully, the estimated and observed total steam consumption figures for a building agreed to $\pm 5\%$ and the electricity figures to $\pm 2\%$.

Labour

The method of fixing labour standards is to make a simple time study of the particular job, and to the number of man-hours required per batch is added a proportion of the time of service men, e.g., weigh men and chargehands. From an examination of the standards fixed by this method and a record of the actual labour utilised, a correction factor has been established for each department.

Maintenance

So far no adequate basis for the *a priori* prediction of maintenance costs has been found, but by an examination of plant repair records over a period of years it is possible to arrive at a figure for the typical maintenance costs of typical plant operating on typical duties. Knowing the approximate annual cost of maintaining a certain unit, this can be brought down to the product by allocating the charges according to the number of batches which could be made in a unit operating on normal runs during the year. We are trying to obtain data so that the types of jobs carried out as maintenance, can be classified and ultimately analysed for control purposes. The one thing that is generally agreed is that, as in most other works, maintenance costs are far too high. This comes back to a question of design.

Depreciation

Depreciation costs are allocated on the basis of dividing the value of a plant by its expected life and the number of batches of product which will be made in it under normal conditions in the course of one year.

Cost Analysis

The standard costs of manufacture of each product arrived at by the above technique have three uses. First, for fixing (or negotiating) the selling price; second, as an examination of the consumption figures per 100 lb. of product highlights those processes which use more services, labour, etc., than the average for the department or works, they lead to attempts to improve manufacturing efficiency; and third, by enabling comparisons of actual usages with expected to be made, a measure of the running efficiency is obtained.

The ultimate responsibility for maintaining a high chemical and manufacturing efficiency rests with the plant managers and, at least as far as yields are concerned, the usual daily control is practised. The main cost control is carried out by the cost office at quarterly intervals and is made on the basis of monthly returns of materials consumed and produced in each plant and the records of steam, electricity, labour, etc., used in each plant. The material usage for each product is compared with the standard, and any deviations from standard is split up into factors arising from changes in the yield on the main starting product and factors arising from the consumption of other materials. The comparison is made on the basis of the value of the materials used so that, for example, if a certain quality of raw material were not available and a more expensive grade had been used, this would show up in the comparison with standard material costs. This, of course, works the other way, so that there is always an incentive for the plant manager to reduce costs not only by improving the consumption figures but by seeking alternative and cheaper materials. As indicated previously, the direct manufacturing costs cannot be compared easily on a product basis, so it is the practice to make a quarterly comparison between actual usages in each department and the usages which have been calculated on the standard consumption figures. Again the comparison is made in terms of £ s. d. so that the difference between the actual and expected figures is analysed for each manufacturing cost and broken down into variations which arise from changes in yield, plant occupation, and manufacturing efficiency. These figures are then tabulated and presented to the higher management, the departmental managers, and the individual plant managers. The punch-card calculator department is able to make the complete analysis within ten to twelve days of receiving all the data and, providing these data are accurate, then the ultimate analysis must be correct because of the system of internal checking used to eliminate the chance of error.

The speed and accuracy of mechanised accounting can lead to attempts to accumulate more statistics than are absolutely necessary and, even worse, to attempts to analyse and interpret the figures far beyond the reliability of the initial information. Clock-hours and materials weights go on to cards at the source and are quite accurate

but it would be no use attempting to reach a conclusion on a single steam figure which happened to be, say, 8% higher than expected. In general, the value of the costing system for plant control purposes is very little since the campaign on a particular product may well be finished before the cost office make the comparison. The capacity lags and line lags are such that no form of "anticipatory" control action can be introduced, but the knowledge that the analysis is to be made means that something in the nature of "retributory" control action is operated. The individual plant managers, once they have the "feel" of the plant, should be able to keep control from daily yield figures and steam consumption and man-hours returns, etc. The cost-office analysis enables long-term trends to be followed and provides the information on which general policy decisions can be made.

Production Planning

It is important, in order to obtain maximum efficiency, that the sequence in which intermediates and products be manufactured should be closely controlled. At regular intervals the colour manufacturing departments receive forward forecasts of demands, parts of which are estimated and parts of which are based on actual orders. An analysis of these is currently made by the departmental managers who break down these figures into the intermediates that they will require, and these figures are in turn passed back to the intermediate manufacturing departments. The actual sequence in which colours and intermediates are made is quite important and this has to be determined in the light of experience of the manager and the capabilities of the plant he has under his control. It is hoped that much of the analytical work associated with this planning will be taken over by the calculator department.

Quality Control

Raw materials are all sampled and tested by the analytical department who advise the manufacturing departments of any departure from purchasing specification and have the responsibility of rejecting materials if they are unsuitable. The analytical department also samples and tests all intermediates which are transferred between departments or packed for sale. This department also carries out certain special tests, for example, on foodstuffs colours, but does not in general, test the final colours, which are tested in the dyehouse, whose staff report on the comparison of the products with type both in respect of strength and shade and in certain other special properties. These two departments are independent of one another and of the rest of the works, and the chief colourist's word is law.

The author wishes to thank the directors of the Clayton Aniline Co. Ltd. for permission to publish this paper.

3. Medium-Sized Factories

by D. F. Stewardson (Thomas Hedley & Co. Ltd.)

THE methods described are employed by a group of three medium-sized factories. They are producing a range of soaps, synthetic detergents and edible fats from raw materials through to the finished retail articles. Continuous and batch processes are employed and the types of products manufactured do not vary greatly from month to month. The volume of production at one of the plants can vary from 20 tons per month to 4,000 for different brands—so we have found our systems to be sufficiently flexible to cover a range of product types and volumes.

We find the most satisfactory approach to cost control is to show under each category the actual expenditure in £ together with the best possible calculation of what the expenditure would have been had every phase of operating been perfect. This we call the "ideal cost". For convenience we divide this ideal cost by the actual cost to give a decimal equal to or less than 1.00 we call the "performance factor". By this factor we endeavour to compare the relative efficiencies of completely different operations or departments provided that there is some common basis to the calculation of the ideal costs. The costs are only calculated for those operations which are essential. We have found it most convenient to divide factory expenditure into four or five sections each of which is supervised by a controller who is responsible for gathering together information on actual costs, calculating and maintaining accurate ideals, presenting the information concisely to management and working jointly with them to reduce expenditure in that particular field. The controllers have an equal status with departmental production managers and their sections normally cover: operating wages; fuel, water and power; plant maintenance, and materials control. Their statements of performance are produced at least monthly and may in certain cases be available weekly or daily so that adverse trends can be more rapidly checked. Our interpretation of ideal operation requires that plant should be running at maximum capacity.

To exclude the influence of those items which are normally outside direct control such as wage rate changes, coal and material prices, etc., we work first in hours worked for wage control, weight of steam, kilowatts, for fuel control and percentages for processing yields and losses on materials control, and convert into £ s. d. at the appropriate wage rate or coal price, etc., at the last stage of presentation. For operating wage ideals the time study standards for all the individual jobs are summarised to show a total number of hours operating allowed ideally for a given weight of product. The method of actually arriving at the individual job time standards—whether by stop watch, synthetics or micro time-and-motion study does not really affect the method of compiling the finished ideal. Though the final answer will be fairly accurate, they require continuous attention to keep them up to date.

Ideals for fuel consumption are the most satisfactory since they are based on heat transfer data, specific heats, latent heats, radiation losses, etc. A complete heat balance for all processes is calculated at the maximum rated production speed. We have not yet found water consumption to be sufficiently large to merit control but this would also be tackled theoretically like fuel. Plant maintenance has proved to be less easy to control accurately.

We divide materials control into subsections as indicated below for ease of control:

(*a*) Known losses can often be ideal because a certain process loss at a given point may be the cheapest way of operating with the equipment available. The ideals are calculated theoretically, statistically or by controlled experiments and expressed as a percentage of product handled.

(*b*) Depreciations of stock to a lower grade material are similar to known losses except that the excess cost may result from degrading too much stock or to an excessively low grade—therefore both the extent of the degrading as well as the percentage will be stipulated.

(*c*) Processing yields will have their ideals established either by pilot plant experiments or statistical analysis of plant operating results. Special treatment is sometimes required for calculating performance factors where yields are commonly very high but the excess cost is still worth controlling due to the high cost of raw materials.

(*d*) Unknown losses are the balance between what was purchased and what was sold as finished product after making allowances for known process losses, depreciations, stock transfers and process yields. Since they reflect the errors in processing, sampling of receipts and shipments and of weighing the ideal unknown loss is always nil.

The essential feature of any control system is that it be so presented that there is a will to make it successful, for without this even the best system will founder.

STEELMAKING REVIEWED

by A. NOEL WHITING, A.I.M.

Notes on developments in steelmaking discussed at an international conference held at Liége

DEVELOPMENTS in both traditional and oxygen steelmaking processes were discussed at an international meeting held at Liége recently under the auspices of the *Centre National de Recherches Métallurgiques*, the *Groupement des Industries Sidérurgiques Luxembourgeoises* and the *Groupement des Hauts Fourneaux et Aciéries Belges*, and attended by representatives of nearly every major steelmaking country in the world.

Traditional Steelmaking Processes

Reporting open-hearth furnace developments, EVANS and colleagues,[1] of Great Britain, pointed out that a series of improvements, including increased fuel input rates made possible by the use of high-pressure gas or atomised liquid fuel, improved burner design, and the use of oxygen-enriched air for combustion of these fuels had created severe conditions and that these, in turn, were encouraging the development and use of basic chrome magnesite furnace roof refractories. The value of aerodynamic studies on scaled models had been proved in their work on making modifications to furnace design. LIGHTNOR and MCBRIDE[2] spoke of the use of furnaces of increased size in American practice and of the closer control of waste gas analysis, charging, refining and pouring. New features they described included the removal of the furnace body in one piece weighing 1850 tons for wrecking and relining of the brickwork, and the use of closed-circuit television for inspecting furnace combustion conditions. Operational details of large electric-arc furnaces of up to 200 tons capacity recently installed in the U.S.A. and Europe, were given by the authors of two papers.[3, 4] In a paper on bottom-blown Thomas converters, ALLARD[5] described French experience in the desulphurisation of iron with powdered lime, and he reported the injection of powdered materials using specially developed pumps to minimise the disadvantage of using high-silicon irons.

Oxygen Steelmaking

Two papers[6, 7] were devoted to the commercial application of the oxygen-air, oxygen-steam and oxygen-carbon dioxide processes in bottom-blown practice. Developed originally for the production of steel with low nitrogen and phosphorus contents from the Thomas iron (1.8/2.0% phosphorus), the oxygen-steam process was claimed to be suitable for refining iron with as little as 0.3% silicon and 0.3% phosphorus. A feature of the process was the product's consistently low nitrogen content of 0.002/0.003%.

TRENKLER[8] had found that the established Linz-Donawitz (L-D) process, originally developed at Linz-Donawitz to deal with low phosphorus (0.2%) Austrian iron, was applicable for irons containing up to 1.4% phosphorus. This development, which is of potentially great importance, as many of the world's sources of iron ore will yield iron analyses within this range, had resulted from the simulation of open-hearth refining conditions in the L-D furnace—by setting the conditions so that the reactions take place through a rapidly liquefied slag. Provided the slag contains lime and is liquid at an early stage in the process, then the phosphorus in the iron is removed to low limits prior to the complete removal of carbon. CUSCOLECA and RÖSNER[9] provided details of the manufacture of high-carbon steels, containing up to 1.0% carbon, by the L-D process.

Metz[10] gave news of the refining of Thomas irons containing up to 2.0% phosphorus by top blowing with oxygen and lime, a development at present operated on a commercial scale in a 26-ton capacity closed-bottom converter. After molten iron has been charged a water-cooled lance is lowered vertically into the converter mouth and oxygen blown on to the metal surface. After five minutes, lime is added to the oxygen stream, the object being to promote a rapidly-fluxed lime-containing slag to ensure the elimination of phosphorus at an early stage. At an iron analysis of 1.0% carbon and 0.2% phosphorus, the slag, containing 2.5% phosphorus pentoxide and from 4.0 to 9.0% iron, is withdrawn from the furnace. A new slag is made and the heat is finished in the normal way.

A report on the Swedish Kaldo rotary process by KALLING and JOHANSSON[11] brought up to date with operating details the commercial application of this process for dealing with high-phosphorus iron (up to 1.9%) and low-phosphorus iron (0.10%). A heat balance showed the advantage to the system of burning the carbon monoxide resulting from carbon oxidation in the furnace. The heat gained allows up to 15% of iron ore (as a percentage of the weight of iron charged) to be added to the furnace. The ore added contains about enough oxygen to balance the requirement for combustion of the carbon monoxide. Thus, on an economic basis, a cheap source of iron, i.e., from raw ore or sinter, can be reduced during the steelmaking process by the heat intrinsic in the iron. The high rate of refractory lining wear which would be suffered in a stationary furnace when burning carbon monoxide in oxygen is mitigated by processing the iron in a converter-type furnace tilted to about 15-20 degrees to the horizontal and revolving the furnace, ensuring that all parts of the lining are periodically submerged, thus using the cooler molten metal to cool the lining. By rotating the furnace at up to 30 revolutions a minute, it is claimed that improved

---

Mr. Whiting *is technical sales manager of Davy British Oxygen Ltd. After some 15 years with the United Steels Co., he took up an appointment as process oxygen manager with the British Oxygen Co.'s interests in Southern Africa, returning two years ago to join the newly-formed Davy British Oxygen.*

slag-metal mixing and thus a lower iron content of the slag is obtained.

Further details were presented by GRAEF and VON BOGDANDY[12] of the German rotor plant which comprises a cylindrical furnace rotated about its cylindrical axis in a horizontal position, and equipped for oxygen injection both below and above the surface of the molten metal through primary and secondary oxygen lances. The primary oxygen oxidises the metalloids in the iron and the main function of the secondary oxygen is to burn the carbon monoxide arising from carbon oxidation. About half of the secondary oxygen is used for this purpose, the remainder reacting in the same way as the primary oxygen. The furnace is revolved at half a revolution a minute to improve heat-transfer between the furnace lining and the molten metal. As with the Kaldo process, it is possible to make an addition of 15% iron ore (as a weight percentage of the iron charged). A notable feature of the process was the high degree of instrumentation and automatic control. A constant refining rate is achieved by control of the total exhaust gas quantity and its carbon monoxide content. Differential pressure indicators and carbon monoxide analysis equipment, specially designed by the operators, work with a lag of about two seconds, and control electronically the depth of the primary oxygen lance, as slight differences in the depth of the primary oxygen nozzle produce marked differences in carbon monoxide content of the waste gas. The exhaust gas is spray cooled and is automatically controlled on the basis of waste-gas temperature.

Conclusion

Although, from the conference, it appeared that the overall trend of steelmaking developments was still not clear, it was evident that: (1) The field of application of each of the new oxygen steelmaking processes is widening —the bottom-blown oxygen processes are being applied to low phosphorus irons; and the L-D process is being developed to deal with a medium phosphorus range. (2) The Kaldo rotor and Oberhausen rotor processes are firmly established commercial operations, dealing with Thomas iron and using a high proportion of iron ore as part of the charge make-up. Reported information on the latter as a steel producer using Thomas iron, however, is scant. (3) The open-hearth furnace is meeting the challenge of these new processes by continuous modification and improvement. (4) The large electric furnace as a production unit is now established. (5) The demand for traditionally-produced Bessemer steel will persist.

CONTRIBUTORS

[1] Evans, R. W., Steel Co. of Wales Ltd. Other contributors: Chesters, J. M., United Steel Companies Ltd.; Kesterton, A. J., Steel Co. of Wales Ltd.; Allen, J. F., Consett Iron Co. Ltd.; Pearson J., British Iron & Steel Research Association.
[2] Lightner, M. W., and McBride, D. L., United States Steel Corp.
[3] Ogan, A. C. and Carney, D. J., United States Steel Corp.
[4] Stassin, G., S.A. Fabrique de Fer de Charleroi.
[5] Allard, M., L'Institut de Recherches de la Sidérurgie Française.
[6] Daubersy, J., S.A. Métallurgique d'Espérance-Longdoz, and Decker, A., C.N.R.M., Liége.
[7] Kosmider, H., Weyel, A., and Neuhaus, H., Klöckner-Hüttenwerke Haspe.
[8] Trenkler, H., Vereinigten Osterreichischen Eisen-und Stahlwerke Aktiengesellschaft.
[9] Cuscoleca, O., and Rösner, K., Osterreichisch-Alpine Montangesellschaft.
[10] Metz, P., l'Arbed/Dudelange.
[11] Kalling, B., and Johansson, F., Storakopparbergs Bergslags, A.G. (Suéde).
[12] Graef, R., and von Bogdandy, L., Hüttenwerke Oberhausen A.G.

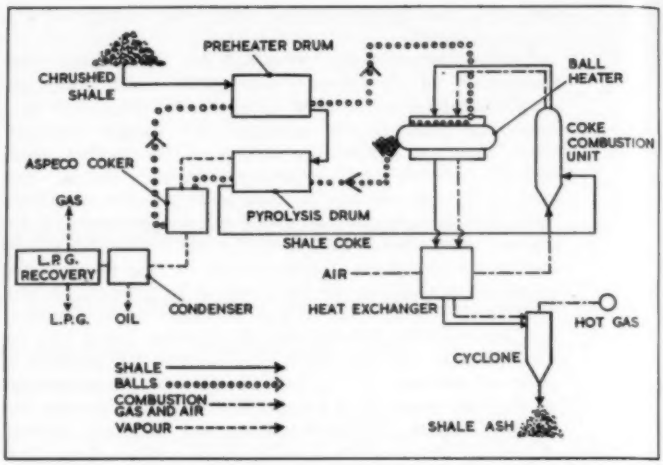
Fawley's £10 million Petrochemicals Plant

NOVELTIES in the design of the £10-million petroleum chemicals plant recently commissioned by Esso at their Fawley, Hants, refinery include the use of air-cooled rather than water-cooled heat exchangers and the employment of a gas-turbine as the prime mover for the refrigerator centrifugal compressors, the heat from the turbine's exhaust gases being recovered by a waste-heat boiler.

With the start of this plant Esso begin a new phase in their activities in Britain and enter the petroleum chemicals industry with the capacity for producing two chemical feedstocks—butadiene and high-purity ethylene in annual capacities of respectively 42,000 tons and 40,000 tons. Most of the output will be piped to neighbouring plants, the butadiene, for example, being destined for the 50,000-tons-a-year GR-S rubber plant of International Synthetic Rubber Co. now on stream (see BRITISH CHEMICAL ENGINEERING, 1958, **12,** 675). The ethylene will go for the production of ethylene oxide and its derivatives, 20,000 tons annually, and of polythene, 10,000 tons annually, at plants soon to be completed by respectively the Union Carbide subsidiary, Gemic Ltd., and Monsanto Chemicals Ltd. A supply of higher olefins will also be available for the general chemical industry. Standard Esso processes are operated at the plant, but they have been tailor-made to suit the refinery streams available for conversion to petroleum chemicals. One of the two key processes, the steam cracking of the C_6 fraction obtained from the naphtha feed, produces the ethylene and 8000 tons a year of butadiene. The bulk of the butadiene, another 34,000 tons a year, is produced in the second key process—the dehydrogenation of the butene obtained from the C_4 stream from the refinery's cat cracker. Both of these key processes have been developed by Esso's research organisation. It is in reducing the temperature of the dilute butadiene solution from the steam-cracker that the air-cooling is used. The installation, said to be the largest air-cooled heat exchanger in Britain, is a Fin-Fan assembly by Head Wrightson Processes Ltd., and it is rated for a heat load of 173 million Btu an hour at a dry-bulb temperature of 90°F. The plant was chosen in preference to water-cooled equipment on the grounds of economy and of reducing pollution and maintenance problems. With the new instalment Esso's investment at Fawley is now £68 million. Although the petroleum chemicals installation has absorbed nearly 15% of this, its products will represent only about 1% of the refinery's feedstock. The output is expected to be a considerable dollar saver as Britain is spending about $30,000 on imported synthetic rubber alone. The refinery will continue to make available for industry up to 28,000 tons of pure sulphur annually.

General view of the chemicals plant showing the ethylene purification unit in the centre foreground.

The new plant, the largest of its kind in the British Commonwealth, covers more than 600,000 sq. ft of land and contains 31 towers, 203 vessels of various sizes, 260 heat exchangers, 168 pumps, 18 compressors, seven furnaces and over 100 miles of process piping.



Left: *Initial laboratory-unit constructed to study the engineering variables. It is shown being operated by Mr. S. A. Johnson, Jun., while Dr. C. H. Prien displays an aluminium-oxide thermosphere.* Right: *Process flow-diagram.*

662.67

NEW OIL-FROM-SHALE PROCESS

A method using a rotary retort fed with heated metal or ceramic balls is claimed to produce fuel competitive with petroleum

THE elaboration of a process for distilling oil-shale deposits which yields fuel oil at costs competitive with those of domestic petroleum was announced in Denver, U.S.A., recently by S. A. Johnson, Jun., director of the Denver Research Institute, and C. H. Prien, head of the Institute's chemistry and chemical engineering division. The claims are based on two years' work which was undertaken for the Oil Shale Corp., Carson City, Nev., and which included operating for nearly a year a 24-ton-a-day pilot plant.

The process, which was entirely on paper when it was drawn to the attention of the Institute, was originally known by the name Aspeco and it is protected by patents in the name of the Corporation. The heart of the process, according to Dr. Prien, is a horizontal rotating kiln in which heat carriers (thermospheres) composed of heated metal or refractory balls are brought into direct contact with the crushed oil shale. Through this solid-to-solid contact, the shale is heated to the pyrolysing temperature of about 1000°F in the absence of air. The heat converts most of the kerogen in the shale to shale oil vapours and retort gases. In the process of decomposition, about two-thirds of the organic matter in the rock is converted to liquid shale oil, 10% appears as gas, and the remainder appears as solid carbonaceous coke on the spent shale. The shale-oil vapours and the gases are withdrawn from the kiln for further treatment, while the residual shale coke and the cooled balls are discharged from the kiln and separated on a screen.

The shale coke contains about 3% organic carbon, which, when burned, will produce some 922,000 Btu per ton (equivalent to 802,000 Btu per ton of shale feed). This coke is used to reheat the thermospheres. It is fed into a fluidised bed and burned with air. The resulting hot flue gases are passed to a ball-heating tower, into which are also fed the cooled balls from the retort. Thus the balls are reheated to retorting temperature and can be returned to the rotating kiln for pyrolysing more raw shale. The spent shale-ash from which the carbon has been burned is at present discarded, but efforts are being made to find uses for it. Burning of the shale coke produces more than enough heat to raise the thermospheres to the required temperature for pyrolysing the shale. This excess heat can be converted into cheap power, a portion of which is required for the retorting. The rest is available for shale mining and crushing and as excess for sale.

The retort gases contain a substantial quantity of light petroleum gases (LPG) which are saleable and can be removed by compressing and cooling the retort gases. The denuded retort gas is still of high calorific value and it can either be sent to a pipeline for sale (after removal of hydrogen sulphide and carbon dioxide) or burned and converted into additional power.

Advantages Claimed

The development work already completed indicates, Dr. Prien states, that the process has the following advantages:

(1) The rotary furnace allows higher through-put rates than are possible with conventional rotary retorts. This is due in part to higher heat-transfer rates attainable through the solid-to-solid contact of the shale and the heated thermospheres.

(2) More rapid pyrolysis of kerogen to shale oil is obtained, residence time in the retort being only 6-10 minutes, compared with 60 minutes and longer in conventional retorts.

(3) The retort is able to handle raw shale in a wide range of sizes. Conventional retorts usually cannot handle finely-crushed shale, which must be screened out. The result is a 15% "loss" of raw material.

(4) Since the oil shale is retorted in the absence of air, there is less chemical degradation of the shale oil obtained.

(5) The retort gases have a higher Btu value than those obtained in conventional retorts (700-1000 Btu versus

80-100 Btu per cu. ft), because they are not diluted with combustion gases.

(6) It is feasible to partially coke the shale oil at the retort, without reheating the vapours.

(7) It may be possible that shale oil can be produced in the retort that is suitable for transmission by pipeline with little or no further treatment.

(8) Cost of retorting the shale oil may be as much as 50% less than that disclosed for any other retorting process so far.

In addition to the retort and the ball-heating furnace, the Institute studied a coker and a preheater drum for the raw shale. The heat required would be furnished by the partially-cooled thermospheres after they have left the pyrolysis drum.

Economics of the Process

In determining the commercial feasibility of the process, a shale plant was selected that would process 19,200 tons a day of shale. This corresponds to the minimum optimum size room-and-pillar unit-mine in which underground mining may be conducted, as determined by the U.S. Bureau of Mines. Since the Corporation's process can handle all shale crushed, including fines, the quantity of shale to be crushed and retorted, it is pointed out, is also 19,200 tons a day. From shale containing 25 gal. of shale oil per ton, this would yield 11,400 bbl. a day of uncoked oil (8900 bbl. of coked oil) and 6,320,000 cu. ft a day of retort gas. For shale containing 30 gpt the yield would be 13,700 bbl. a day of uncoked oil (10,700 bbl. a day of coked oil) and 7,580,000 cu. ft a day of retort gas.

The shale oil produced by this process, without coking, has a gravity of 20 degrees API, a nitrogen content of 1.6%, a sulphur content of 0.7% and a pour point of 70-80°F. Preliminary tests show that this oil may be sufficiently fluid for pumping down to a temperature of 30°F without further treatment. The coking unit, which can be made integral to the retort itself, can reduce the pour point to 20-30°F with, of course, a corresponding reduction in yield.

The retort gases contain about 30% carbon dioxide, 25% hydrogen, 1.5% hydrogen sulphide and 43.5% LPG and light hydrocarbons. The most economical means of processing this gas is probably refrigeration to recover 427 bbl. a day of LPG (510 bbl. a day from the 30 gpt shale). This LPG can be blended with the shale oil and piped to California in the same line. The residual gas, after removal of the LPG, can be flared, used for power generation at the site, or further processed for sale as fuel gas. In these studies, however, it was assumed that this gas would be flared, so no credit was taken for its sale.

Retorting drums 8 × 20 ft, with a throughput of 2400 tons a day, were calculated to be representative of sound but conservative engineering scale-up. A 19,200-tons-a-day plant would require eight such drums. Larger drums probably would be used after further scale-up data had been obtained. These would reduce calculated retorting costs.

Mining costs were based on U.S. Bureau of Mines estimates made in 1954, and were modified after consultation with several mining companies to reflect 1958 costs. Pipeline costs are based on existing pipeline tariffs and costs per barrel-mile. It is possible that these costs may require some later revision upward to allow for the nature of the terrain to be traversed. Capital requirements for a plant of 19,200 tons a day capacity would be $22,992,650; this includes facilities for crushing, retorting, coking and LPG recovery. Total costs per barrel for producing shale oil from 25 gpt shale (exclusive of interest on invested capital or construction capital, profit, federal income tax, credit for depletion allowance, or royalties) are as follows:

	10-year Plant Depreciation ($/bbl.)	*20-year Plant Depreciation ($/bbl.)*
Mining	0.780	0.780
Crushing	0.170	0.143
Retorting	0.673	0.452
LPG Credit	−0.037	−0.047
Pipeline to California ...	0.338	0.338
Total Cost of Crude Shale Oil in California ($/bbl.)	$1.92	$1.67

On the same basis, but using 30 gpt shale, the total cost of crude shale oil in California exclusive of profit would run $1.65 per barrel for a plant depreciated over a 10-year period and $1.42 for a plant depreciated over 20 years. These costs are lower than any previously reported for delivery of shale oil to the California market the Institute point out, and are the basis for its statement that shale oil is now believed to be competitive with petroleum crude.

Helium Separation by Diffusion

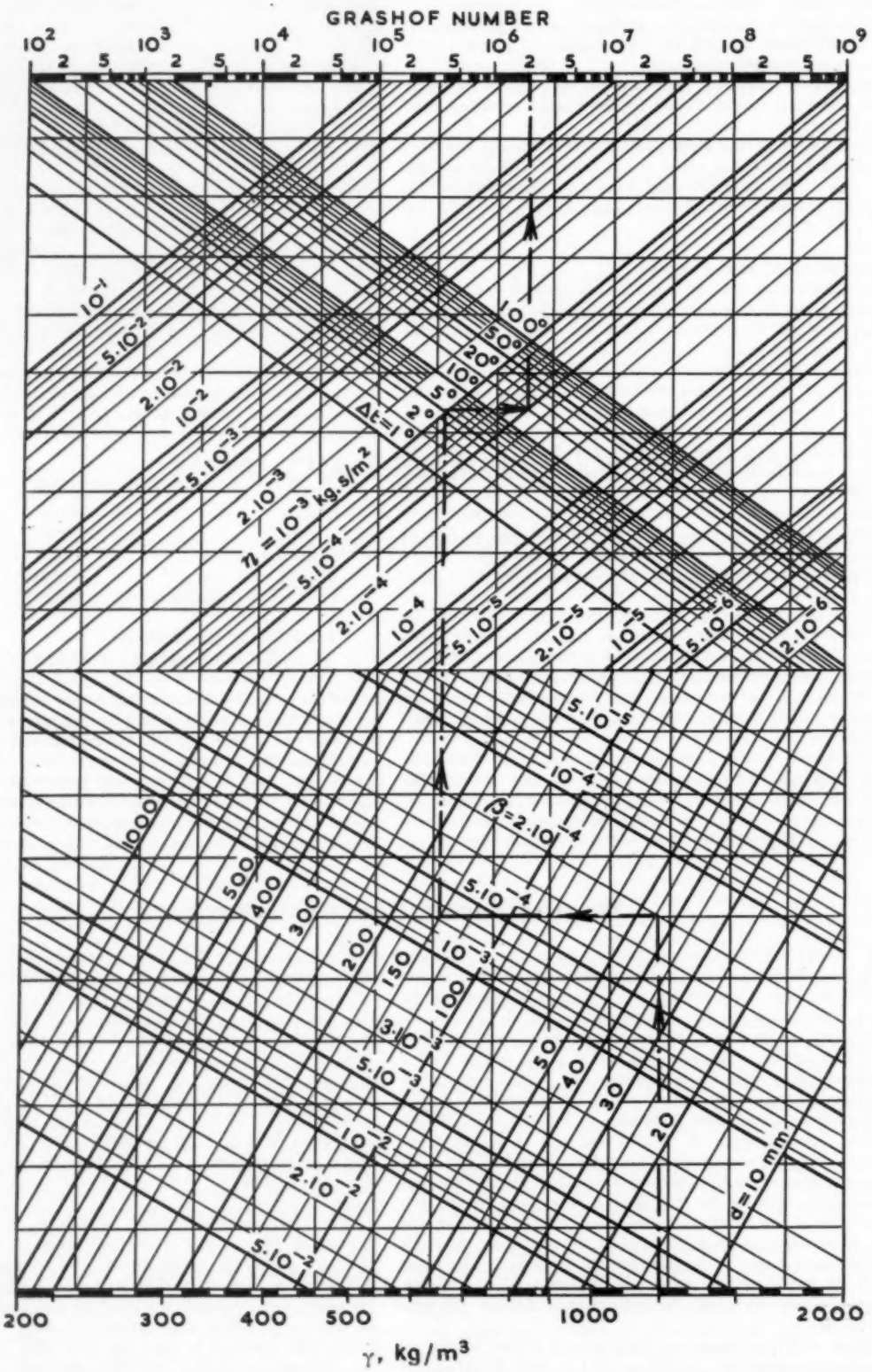
A DIFFUSION technique for the separation of helium from a mixture of gases has been elaborated at the Bell Telephone Laboratories, U.S.A., and it promises to have application to the commercial isolation of the element from natural gas. Differential diffusion through glass is the principle employed and silica glass, which has a permeability to helium 1000 times that to hydrogen, has been found the most efficient permeable material.

To obtain appreciable quantities of helium, the elaborators of the technique, K. B. McAfee and H. Kraft, point out, a large surface of glass must be exposed to the mixture, the glass must be thin, and a high pressure differential maintained between the two sides of the glass. In practice a bundle of the capillary tubes, each with one end sealed off, is encased inside a large glass or steel pipe, through which natural gas or impure helium is passed. The open ends of the capillary tubes are sealed into a common header which takes off the helium that diffuses through the walls.

Silica or Pyrex which can be drawn to tubing having an external diameter of 2/1000 in. and a wall thickness of 2/10,000 in., and is capable of withstanding a compressive stress in excess of 1000 atmospheres, is ideal, Bell say, for the separation of helium. It will withstand temperatures of more than 400°C over long periods without deteriorating, and tests have indicated that a cell containing enough capillaries to occupy about 2 cu. yd would pass nearly 1000 cu. ft a day of helium at room temperature with a pressure differential of 1000 atmospheres, assuming a concentration of 1% helium. At 400°C it would recover 1,000,000 cu. ft of helium a day. A cell of that type might be placed directly in a gas pipeline for industrial use. A single diffusion step, it is claimed, yields helium containing less than 0.0009% hydrogen from a 90:10 hydrogen-helium mixture.

The only present producer of helium in the U.S.—the Bureau of Mines—has established several low-temperature recovery plants in the South-west to salvage some of the helium from especially rich, natural gas-helium mixtures. However, most wells do not produce a rich-enough mixture to warrant building such plants, so most of the natural gas-helium mixture is used for fuel, Bell point out, and the volume of helium so lost amounts to more than 10 million cu. ft a day.

DETERMINATION OF THE GRASHOF NUMBER



Example: $Gr = \gamma^2 \beta \Delta t d^3 / \eta^2 g$ is solved for specific weight $\gamma = 1200$ kg/m³ volumetric coefficient of expansion $\beta = 2$, 10^{-4}(°C)$^{-1}$, diameter $d = 150$ mm. temperature difference $\Delta t = 5$°C., viscosity $\eta = 5.\ 10^{-4}$ kg.s/m², $Gr = 2.10^8$.

(Published by courtesy of *Chemicky Prumysl*, Prague)

British Chemical Engineering
NOMOGRAM NO. 33

BCE 4665 for further information

Put **MINISPACE** on your staff.

A Solartron analogue computer can be your most profitable employee!

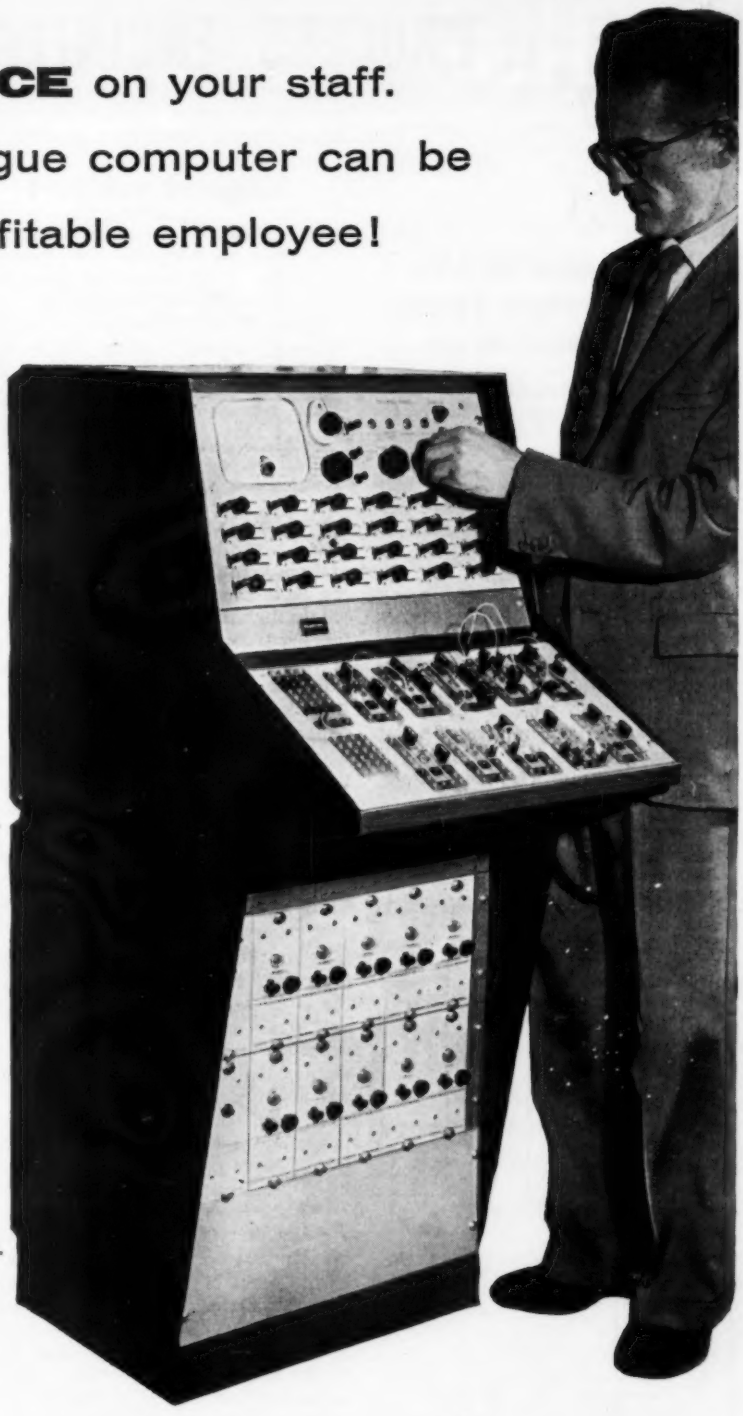
The analogue computer is the supreme design tool for all dynamic problems. It rapidly repays its cost by savings in engineering development time. Proven in the aircraft industry and now developed by Solartron to the highest orders of accuracy, flexibility and reliability, you too can prove that *it is much cheaper to simulate your mistakes than to make them!*

Contrary to general belief, a computer need not be expensive or difficult to use. Solartron MINISPACE costs only £1,600 — a fraction of the amount often lost in making "trial and error" models — and does not require a specialist operator.

MINISPACE is just one example of the SPACE* construction principle, which allows a computer of any size to be assembled if necessary in phase with your budgetary programme. For more complex problems, SPACE '48' is a typical larger Solartron computer with 48 or more operational amplifiers, many non-linear units, removable problem board and digital voltmeter programming. There is infinite scope for expansion or tailoring to individual requirements.

Solartron advisory engineers will be happy to discuss your problems. Analogue computer application report and literature are available on request.

* SPACE: Solartron Precision Analogue Computing Equipment.



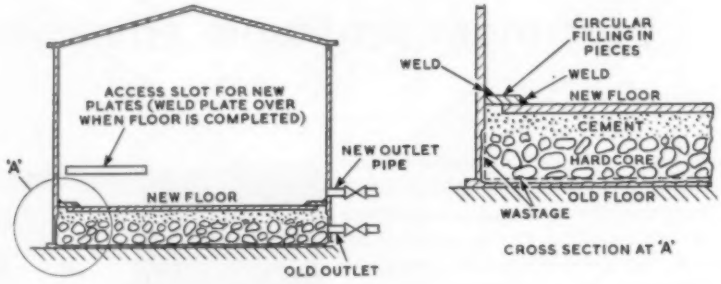
SOLARTRON

THE SOLARTRON ELECTRONIC GROUP LIMITED

Thames Ditton, Surrey. Tel: EMBerbrook 5522 Cables: Solartron, Thames Ditton

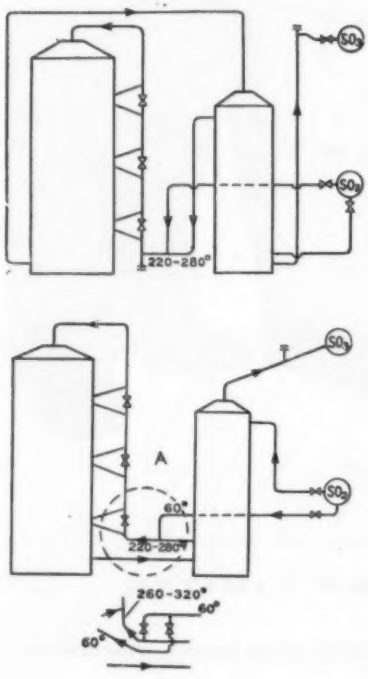
PROCESS ENGINEER'S NOTEBOOK

New Lease of Life for Mild-steel Tanks and/or Hot Wells



GENERALLY, WHEN MILD-STEEL tanks corrode away, get thin and start persistently leaking at the base, they are scrapped and replaced. Frequently, however, it will be found that serious wastage is confined to the base and to the sides up to the sludge line, which may be 6 in. or 12 in. above the base. The sides and roof will in many cases be quite sound and fit for many years of further service. The writer has, by the following method, given several old tanks, ranging in capacity from 5000 to 100,000 gallons, a new lease of life with only a slightly reduced capacity. One must decide first of all the level at which the metal in the walls is sound. This decides the level of the new floor. The bottom of the tank is now filled with hard core, topped by a cement rendering about 3 in. thick, screeded off to form a flat base for the new floor. If any outlets are required through the bottom of the tank, these should be put in and led through the side of the tank before the hard core and cement rendering are put in. If new outlets through the side are permissible, this facilitates the job and outlets may be put in just above the new floor level after this is completed. It is advisable to make the new floor in sections to a diameter about 1 in. less than the inside diameter of the tank, cutting and bevelling the plates ready for welding. If the vessel has a closed top it will be necessary to cut a horizontal slot in the side to allow access for the new plates. This slot is easily welded over on completion of the job. The new floor should now be welded at all seams, except round the circumference, which should be finished last, using curved filling-in pieces as shown in the sketch. If this method is adopted, a flat floor without distortion can very easily be obtained. The cost of a repair by this method is approximately $\frac{1}{5}$ to $\frac{1}{6}$ the cost of a new tank.

Lowering the Resistance of a Contact Unit



IN CONTACT sulphuric acid plants the maximum hydraulic resistance is in the contact unit and may be as high as 130 mm mercury. In one plant, in order to lower the resistance of this section, the earlier arrangement of the gas line was replaced by a new one, as a result of which the number of bends and branches was reduced, the length of the gas line was reduced also by 23 m., and resistance lowered by 7-10 mm Hg.

Fears that the new method would cause premature wear and breakdown of the tubes of the external heat exchanger proved groundless. The experience of more than three years operation with the new design has shown that the working life of these tubes does not depend on whether the cold gas passes into the upper or lower part of the heat exchanger, but on the extent of removal of sulphuric acid mist from the gas and of vapour as well as the means used to protect the tubes from erosion at the inlet of the cold gas into the plant.

In order to lower the resistance of the contact units an annular vanadium catalyst was used for the contacting layers with a corresponding increase in the layer depth. Resistance of the contact unit in this way was actually reduced by 15 mm, although at the same time there was also a marked falling off in the degree of contacting. Thereafter, the annular contact mass was packed only on the first and second layers, where pulverising and sintering of the mass are most likely to occur and where therefore a pronounced increase in its resistance is to be expected. But at the third and fourth layers the maximum depth of granulated mass was used.

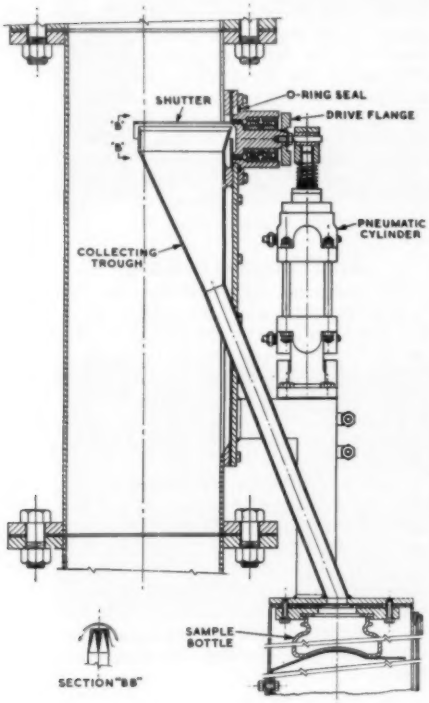
With the use, in four-layer contact units, of a low internal heat-exchanger/mixer, the resistance—according to the amount of SO_2 passing through—may be as high as 38 mm Hg. Occasionally, the lower layer of the contact mass may become heated, since the existing cooling surface of the lower heat exchanger is fully used, so that it is not possible to lower the temperature of the gas passing over the fourth layer. Since the

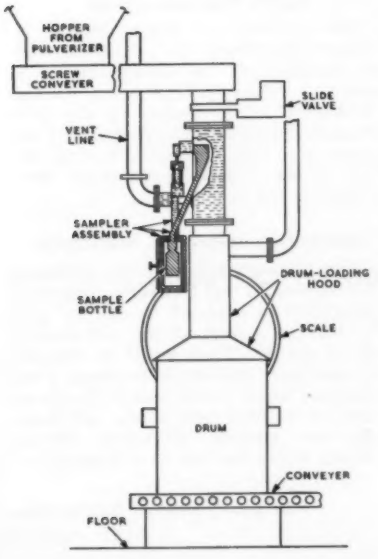
high resistance of this section is an obstacle to greater utilisation of the contact plant, the unit A shown in the second diagram was introduced. This arrangement permits cooling of the SO_3 from the third layer with gas at 60°C instead of at 220-280°C, and since there is a considerable reduction in the amount of gas passing through this heat exchanger the resistance of the contact unit is reduced by a further 34 mm; this allows the gas load of the plant to be increased and less power to be consumed. Moreover, the temperature of the gas at the inlet of the fourth layer can be maintained at the optimum and within easily controlled limits. This effectiveness of this alteration can be judged from the fact that the gas load was raised by 12% in feeding cold gas to the lower internal heat exchanger.

Sinyavskii, V. V. *Khim. Promyshl.*, 1957, **4**, 51.

Powder Sampler

THE MECHANISM OUTLINED here was evolved to meet the need for a method of obtaining representative samples from batches of powdered material; samples obtained by manual "grabs" from drums containing the powdered material were not considered satisfactory.





The automatic proportional-type sampler was designed to meet the following requirements:

(1) Samples obtained should be consistent, non-selective and representative of the product material throughout the loading process.

(2) The sampler must be adaptable to bulk-loading as well as drum-loading equipment.

(3) Sample quantity should be adjustable to provide the proportional amount required.

(4) Sampler should not hold up product material.

(5) Maintenance requirements and operator attention should be minimised.

(6) The assembly should be easily installed, with minimum interruption to the loading process.

As installed, the sampler embodies the principle of an oscillating slotted "shutter", which momentarily admits a small increment of process material, flowing vertically downward, to a horizontal collecting trough. A 6-in.-diameter spool piece was modified to provide for attachment of the trough and other parts of the assembly. Material entering the trough drops into a sample bottle, retained in place within a vented cabinet by a flat leaf spring. The upper figure shows the component parts of the sampler.

Details of construction are shown in this diagram. The shutter, supported by two sealed and shielded ball bearings in a housing bolted to the main attaching flange, is the only moving part exposed to the product. Two neoprene O-rings provide a seal against process material. A double-acting, pivot-mounted air cylinder imparts oscillatory motion to the shutter through an eccentric drive pin. Impulses from a timer, at approximately five-second intervals, actuate a four-way solenoid valve which, in conjunction with two adjustable flow-rate valves, controls movement of the pneumatic cylinder.

In both extreme positions of the drive pin, the shutter effectively covers the trough to prevent entry of material. As the shutter slot indexes with the trough entrance at the midpoint of its stroke, a small increment of product is admitted to the sample bottle. The amount of sample collected can be readily controlled by (1) adjusting the frequency of oscillation by varying the timer cycle, or (2) adjusting the speed of shutter movement by means of the flow-rate valves. This type of shutter motion precludes any hold-up of process material in the sampler and ensures an even distribution of sample throughout the batch cycle.

All components are attached to a flange-and-frame weldment. Thus, removal of the sampler assembly for necessary maintenance and replacement with a blank flange may be effected in approximately 30 to 45 minutes without disturbing the spool piece. No routine maintenance is required. All the operator has to do is to place the bottle in position and to remove it when the desired sample has been obtained.

Before installation, the sampler assembly was tested in the laboratory, using Portland cement in a hopper with inclined baffles to simulate process material flow from a conveyer. Arrangement of the sampler equipment at the loading station is shown in the lower diagram. The spool piece is oriented in the vertical pipeline so that the shutter and trough are directly beneath the discharge of the conveyer.

This sampler was described by W. R. KENNEDY, JR., of E. I. du Pont de Nemours, in an A.E.C. Research and Development Report, DP. 231.

Contributions invited

THE EDITOR invites readers to submit, for possible publication in "Process Engineer's Notebook", notes on practical devices that have been elaborated on the job for improving the operation or increasing the safety of processes, or that have been extemporised in special circumstances. The contributions preferably should be of about 250-500 words, and be illustrated with a line diagram or sketch, or a photograph. A minimum of three guineas will be paid for each contribution used. They will be published anonymously or under the contributor's name, according to his wishes.

World of Chemicals

Nickel Retrospect and Prospect

Reviewing the nickel industry during 1958, Dr. John F. Thompson, chairman, The International Nickel Co. of Canada Ltd., said at Copper Cliff, Ontario, recently that the free world had attained a new high in annual nickel production capacity—about 525 million lb. or almost double the capacity existing prior to the Korean conflict. Nickel consumption in the free world during the year was expected to be between 325 million and 335 million lb., compared with about 415 million lb. in the previous year. The principal cause of the decrease was the business recession in the U.S.A. and Canada. The consumption had been divided as follows: stainless steels, 28%; engineering alloy steels, 16%; nickel specialty alloys, 16%; foundry products, 15%; electroplating, 14%; copper and aluminium base alloys, 6%; miscellaneous, 5%. Heat exchanger applications continued to be the major market for cupro-nickel alloys containing from 10 to 30% nickel, he added. The 1958 consumption of chemical nickel for catalysts, ceramics and salts was substantially reduced from 1957 as a result of curtailed business activity. A nickel catalyst, essentially calcium-nickel-phosphate, however, had played an important part in the expanded European petrochemical production of a variety of synthetic rubber.

Concluding his review, Dr. Thompson said that consumption in recent months had shown an improvement over the low levels touched earlier in the year, and the trend was expected to continue into 1959.

Nitrogen Over-produced

Aikman, brokers, state in their annual report on the nitrogen industry that although for the last few years production has exceeded consumption — in 1957/58 by about 225,000 tons—the temporary estimated surplus should not widely disturb the market if the necessary co-operation among producers takes place. Stocks in Europe at June 30, 1958, were estimated at under 300,000 tons, only 6% of the production, and they were represented largely by ammonium nitrate (particularly 20½%) and urea. Both in the U.S. and Europe the largest producers have tended to reduce production because of low prices. In the U.S., plants are probably only working to about 75% of capacity and in Germany, France, Belgium and Italy the largest producers probably at not more than 80% capacity. In ammonium sulphate production is more or less in balance with consumption now that major reductions have taken place because of the high costs. New plants are being erected in Greece, Turkey, Iran, Egypt, India, Pakistan and the mainland of China, but these represent long-distance increases and for the next two years the expected production is unlikely to increase beyond the figures at present known.

Chemicals in India

India's first commercial blasting explosives factory was opened recently at Gomia, Bihar. It has been built by Indian Explosives Ltd., a company in which Imperial Chemical Industries Ltd., through their Indian subsidiary, are in partnership with the Government, and it was designed, erected and commissioned by I.C.I.'s Nobel Division. Its capacity is 5000 short tons of explosives a year, but plans are already in hand to increase this to 7500 tons.

A party of Russian experts who visited India recently to discuss with the Indian authorities the Soviet Union's offer of technical and financial assistance for the development of the Indian pharmaceutical industry are said to have advocated the establishment of the following units: a synthetic drugs factory; a plant-products research laboratory and plant-extraction factory; and plants for the manufacture of glandular products and antibiotics. The party visited a number of possible sites for the recommended factories.

Among the allocations that are increased in a reappraisal of India's Second Five-year Plan recently laid before the Indian Parliament are those for the Nangal Fertiliser Factory, for the development of the manufacture of intermediates for dyes and drugs, for drugs, and for oil exploration.

Montecatini Polymer Plans

At Montecatini's annual general meeting recently, the chairman spoke of the technical success gained by Prof. Natta in the manufacture of olefin derivatives, and he announced that the company had decided to set up plants for the production of several tens of thousands of tons per annum of polypropylene and of other polymers. The output from the plants now operating in Ferrara would be raised to 20,000 tons of Moplen, with the possibility of subsequently increasing this production to 30,000 tons per annum. The size of the cracking plants would be correspondingly increased to supply the propylene. A new large petrochemical unit is to be established in Southern Italy and the propylene obtained will be partly utilised for the production of polypropylene.

Bolivian Oil's Progress and Plans

The recently-published report for 1957 of the Bolivian state oil industry, Y.P.F.B., records satisfactory progress during the year and highlights an 11.9% increase on 1956 crude oil output, the construction from their own resources of the Camiri-Santa Cruz pipeline, the building of gas plants in Camiri, and a 60% increase in oil exports to produce a total foreign exchange income in 1957 of U.S. $4,652,415.

In his inaugural speech, the new general manager, Alfonso Romero Loza, said that the industry's immediate aims were an increase in their proved reserves of oil and the achievement of a reasonable level in oil exports.

Acid Plants

Simon-Carves have received through their subsidiary company, Simon-Carves (Africa) (Pty.) Ltd., Johannesburg, an order approaching £400,000 for a pyrites-burning sulphuric acid plant to produce 120 short tons of acid a day. The plant will be built for the Harmony Gold Mining Co. Ltd. in the Orange Free State.

A 115,000-tons-a-year sulphuric acid plant has just been completed by Saint-Gobain at its Saint-Fons works, in the Rhone department of France. It will use pyrites from the neighbouring Sain-Bell mine and the heat liberated during the roasting of the ore will be recuperated and converted into electrical energy for the works. Another plant, for the manufacture of sulphuric acid from sulphur, is to be erected at Saint-Gobain's Oseraie works in the Vaucluse. It will have a productive capacity of 80,000 tons of sulphuric acid a year.

Dye Production in U.S.A.

The domestic output of dyes in the U.S.A. in 1957 was 143 million lb.—6% less than in 1956 and 15% less than in 1955. Sales amounted to 127 million lb, valued at $164 million, in 1957, compared with 155 million lb., valued at $185 million, in 1956—a decline of 18% in quantity and 11% in value.

U.S. Vegetable Oil Venture

General Mills has purchased a half-interest in the Nebraska safflower processing plant of the Pacific Vegetable Oil Corp. in furtherance of a joint safflower oil venture begun by the two companies in 1957. About 20,000 acres of safflower were planted in 1958 in Nebraska alone and a fair crop resulted, the companies report.

Dutch Pharmaceuticals

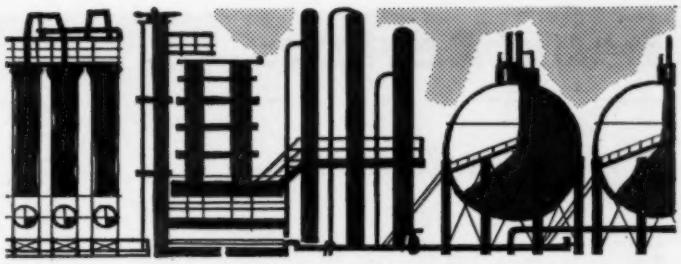
The factories of Merck Sharpe & Dohme Nederland N.V., Haarlem, will be extended by the construction of a new G 3 million (£285,000) plant for the production of a diuretic 6 chloro-7-sulphamyl-1,2,4-benzothiadiazine. The extensions will practically double the size of the original plants which were commissioned in 1957.

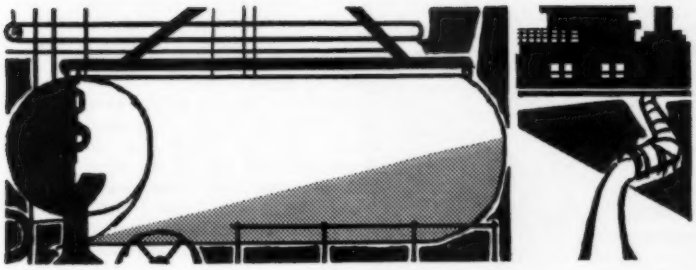
Norwegian Industrial Investment

The Norwegian Minister of Industries has announced that Norwegian industrial investment is expected to rise by 10% in 1959 to a total of Kr. 770 million (£37.5 million). More would be invested in equipment and less in buildings. Four concerns which would account for about 30% of the total were Aardal and Sunndal and Mosjoen Aluminium Works, Norsk Hydro and the Esso Refinery.

BCE 4666 for further information

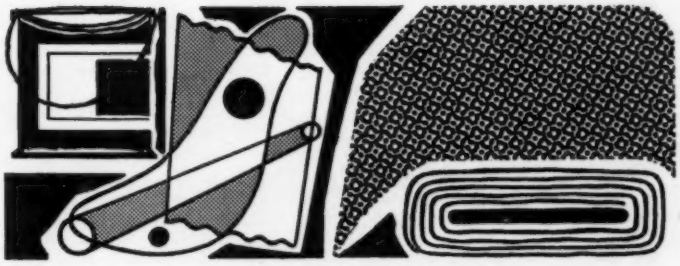
catalysts





aluminium sulphate

organic titanium compounds



SPENCE

CHEMICALS FOR INDUSTRY

At the centre of industry are Spence chemicals; catalysts for the petroleum refining industry, aluminium for paper making and water purification, and organic titanium compounds for the paint, plastic and textile industries. Spence chemicals are renowned for their consistency, reliability and quality.

PETER SPENCE AND SONS LIMITED, WIDNES, LANCS. Also at London and Bristol

Book Reviews

The Kinetics of Vinyl Polymerisation by Radical Mechanisms

by C. H. Bamford, W. G. Barb, A. D. Jenkins and P. F. Onyon
Academic Press, New York, $8.80.
Butterworths, London, 1958, 50s.

Physical Chemistry of High Polymers

by M. L. Huggins
John Wiley & Sons Inc., New York.
Chapman & Hall, London, 1958, 175 pp., 52s.

WITH the increasing application of polymeric materials and the consequent interest in their formation and properties, it has been inevitable that the number of books published on the subject has steadily increased. Until fairly recently these have usually attempted to give a comprehensive coverage of the field. It is a true reflection of the present state of maturity of the subject, however, that in the last few years the nature of books on polymers has tended to change in the sense that they now deal with more limited topics within the wider field. Butterworths, in particular, is performing a great service to polymer science in producing monographs of this kind. The book by DRS. BAMFORD, BARB, JENKINS and ONYON is one of these and is entirely devoted to the narrow but eminently important field which is completely defined in the title.

After a general introduction dealing with the elementary steps, in addition to polymerisation and the derivation of the kinetic equations (Chapter 1), the authors discuss the theory underlying the derivation of the various rate constants in the polymerisation process (Chapter 2). This is followed by a description of the homogeneous polymerisation of specific monomers. Chapter 4 deals with heterogeneous radical polymerisation in all its aspects. The title, of course, specifically excludes polymerisation initiated by the newer heterogeneous catalysts of the Ziegler type, and although these are of intense current interest the authors are probably right in stating in the preface that the present is not the right time for detailed review. Graft and block copolymerisation are included in the discussion of copolymerisation (Chapter 5). Finally, there is a most useful chapter on statistical aspects of vinyl polymerisation.

This book is written by four authors with high reputations in the field and they have gained the maximum advantage from their multipilicity. From the uniformly high standard of presentation, it is clear that they have worked closely together so that the conception and execution of their task is the product rather than the sum of their minds.

This book must therefore make a strong appeal to the specialist as an authoritative, up-to-date and thorough review of the subject. But it must also be among the best books available to those who, with some background of polymers, wish to learn more of the fundamentals.

DR. HUGGINS' book is based upon a series of lectures delivered in Osaka and Kyoto Universities in Japan in 1955-56. The subject-matter reflects in particular DR. HUGGINS' own very extensive and valuable contributions in the field.

In the first three chapters the author builds up a very clear picture of the formation and structure of synthetic polymers of all kinds, the understanding of which requires little or no previous knowledge of polymers. Chapters 4-7 deal with the thermodynamics of polymer solutions, and this is followed by chapters (8-10) on the viscosity of dilute solutions, plastic flow, and long-range elasticity. The rest of the book is devoted to a discussion of structural problems in which the author has been particularly interested.

This book is an excellently written and constructed synoptic account of DR. HUGGINS' work and interests in the high polymer field and, as such, must find a place in every collection of books on polymers. It would be difficult to find a clearer and more concise account of the topics dealt with, but it should be emphasised that, despite the title, this is not a comprehensive study of the physical chemistry of high polymers.

N. GRASSIE

Fundamentals of Paper-making Fibres

Edited by Francis Bolam
British Paper and Board Makers' Association, 1958, 487 pp., 75s.

IN a world where the number of scientific journals published is so large that even covering abstracts in a particular field is becoming impossible, increasing dependence on the symposium is inevitable. Besides bringing together in convenient form papers and bibliographies from many countries, it has the more important task of bringing the scientists together and getting them to record their opinions of each other's work. The present volume gives the proceedings of a symposium held at Cambridge in September, 1957, and the editors and printers deserve great credit for the speed of its appearance. The discussion is very full and authoritative.

The paper industry is the largest chemical process industry based on a living natural product and the only one which has shown no signs of decline or replacement by large-scale synthetic chemistry. Although its growth largely depended on empirical methods in the early days, its expansion today is based on a considerable scientific research which has achieved increased efficiency, modified or new processes and ability to use fibrous materials previously unsuitable.

The volume is divided into four sections. The first, on the morphology of pulp fibres, relies very considerably on the electron microscope. As with other biological materials a feature that has been revealed, which was never apparent with the light microscope, is the presence of helices in fibre-wall structure, particularly well shown in the paper by BUCHER.

The second section on the chemistry of pulp fibres includes a paper on advances in organic chemistry of hemicelluloses (HIRST), a very ingenious study of distribution of chemical constituents through the cell wall, using spectroscopic techniques (LANGE), and a practically valuable examination of reaction wood by DADSWELL *et al.*

The third section on properties of bonded-fibre assemblies runs into the third (on beating), as it includes two papers on the influence of beating on paper properties (STEENBERG and BRECHT). CORTE's paper on porous structure of paper brings a further recently-developed family of techniques into the study of paper.

Finally, six papers on the beating process bring an array of techniques and theory to the study of the most mysterious and one of the most important processes in paper manufacture. While the process cannot yet be considered to be completely understood, the present position is admirably summarised.

The book is well printed and illustrated and not too unreasonably priced. Unfortunately, it has no index, either of subjects or of contributors to the discussion. Anyone involved in the practical side of the paper-making industry will find here a wealth of ideas which are sure to help him in solving his day-to-day problems.

V. R. GRAY

Aliphatic Fluorine Compounds, by Alan M. Lovelace, William Postelnek and Douglas A. Rausch. A.C.S. Monograph No. 138. Reinhold, New York; Chapman & Hall, London, 1958, 370 pp., 100s. In this book there is a comprehensive treatment of the preparation and properties of all classes of aliphatic fluorine compounds. The subject is approached from the point of view of preparative organic chemistry and is arranged in a general order similar to the arrangement of treatises on classical organic chemistry.

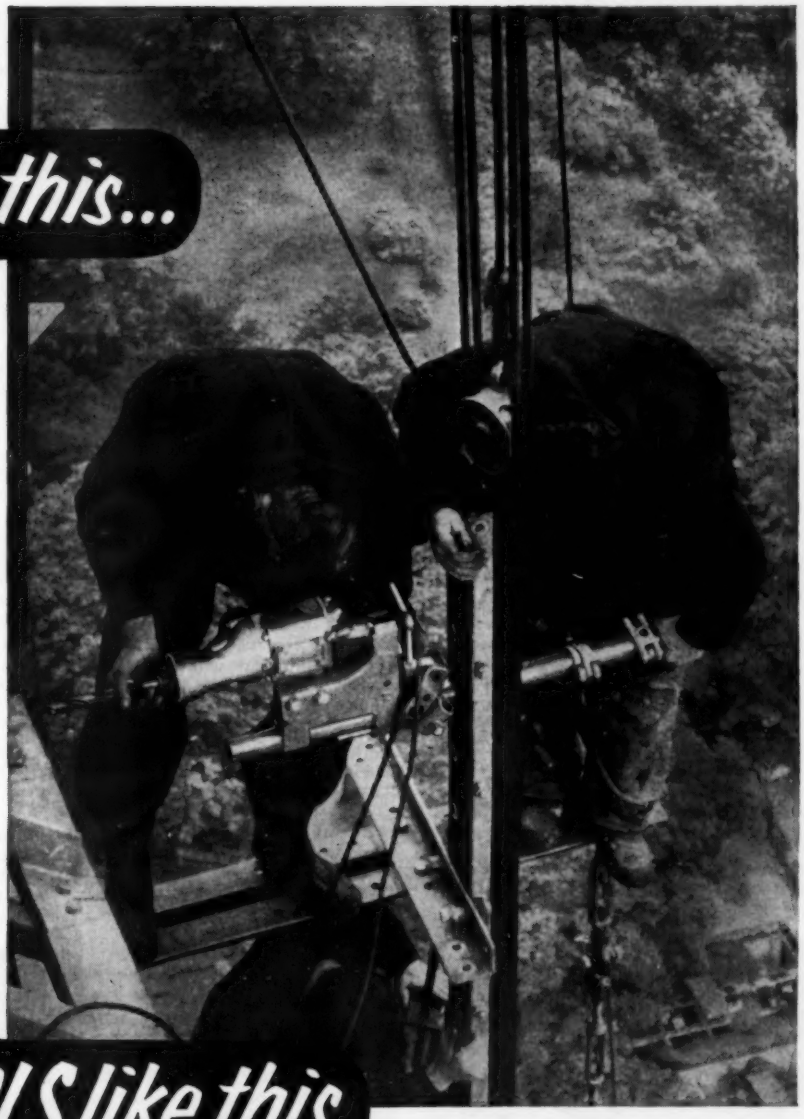
Abstracts of Third International Seaweed Symposium, Galway University College, Galway, 1958. Papers are grouped under the section headings biology, utilisation and chemistry.

Guide to U.K.A.E.A. Documents

Edited by J. Roland Smith,
U.K. Atomic Energy Authority, 1958, 20 pp.

THIS GUIDE GIVES a general description of the form in which U.K. Atomic Energy Authority information is published, with special reference to its own publications, and of their availability to the public. The main groups of the authority and depository libraries are listed and information given on the limited availability of certain classified documents.

JOBS like this...



Spidermen using Wolf 1" drill on 700 feet B.B.C. Television Tower.
(*Courtesy B.B.C. and B.I.C.C.*)

...need TOOLS like this

1" HEAVY DUTY ELECTRIC DRILL Type NW8

BRIEF SPECIFICATION

Drilling Capacity:
In Steel ... ... 1"
In Hardwood ... ...2½"
Spindle Speed on full load...230 r.p.m.
Watts input on full load...1250

Whether it is for 10,000 consecutive holes 400 feet above ground or just for maintenance purposes there's nothing on earth to beat the power and stamina and dependability of Wolf Heavy Duty Drills.
The 1" capacity drill type NW8 as illustration, is also available with reversing switch and other accessories including Bench Drill Stand and girder clamps.

"Wolf the work"

★ *Write today for full details of this Drill and other Wolf Tools.*

WOLF ELECTRIC TOOLS LTD · HANGER LANE · LONDON W.5 · Telephone: PERIVALE 5631-4

PLANT EQUIPMENT NEWS

Glass-fibre Air Filters

A new matrix, Fibreglass tissue in a corrugated multi-layer form, is used in air filters V4 and V5, recently produced by Fibreglass Ltd. The filter medium will not felt in humid conditions, it is pointed out, and performance tests with both filters show that the initial efficiency with test dust No. 2 is 90% for the V4 and 98% for the V5. Initial resistance at 300 fpm of the V4 is 0.08 in. w.g. and of the V5 0.28 in. w.g. The filters are available in a wide range of sizes and thicknesses. **Fibreglass Ltd., St. Helens, Lancs.**

BCE 4723 for further information

High-temperature Coupling

King Aircraft Corp. are making available a pipe coupling developed and tested for pressures in the 6000-psi range. The unit, the Conoseal, is based on the Vee-Band clamp principle and consists of a male and female flange and an all-metal gasket, the flanges being suitable for either lap or butt welding to the pipeline or duct. The standard range covers pipe bores from ¼ to 10 in. in diameter and it can be supplied in aluminium alloy, mild steel, stainless steel or inconel. Non-standard couplings have been manufactured up to 36 in.

diameter. Operating temperatures range from −184°C to +980°C. Speedy in use, the coupling is resistant to liquid carbon dioxide, liquid nitrogen and liquid sodium and it is being applied to coolant and purging systems for atomic power plant installations, aircraft fuel systems and missile applications associated with cordite gases, the makers say. **King Aircraft Corp., Hillington, Glasgow, S.W.2.**

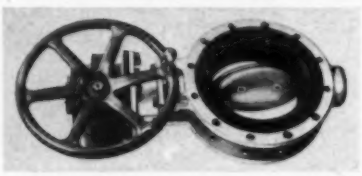
BCE 4724 for further information

Two-way Shut-off Couplings

Series HK two-way shut-off couplings for hydraulic, pneumatic and vacuum lines by Hansen Manufacturing Co., Ohio, are now available in Britain from Guysons. A pull-back sleeve disconnects the two halves of the couplings and an instantaneous seal is provided by a torpedo-type of valve in the plug and socket. When the halves are connected, a positive seal is formed by compression of an "O"-ring in the socket. Models are available for a complete range of pipe sizes from ⅛ in. to 1 in. and for working pressures up to 5000 psi. Special Hansen couplings are also available for handling liquid foods, oxygen, acetylene, steam, etc. **Guyson Industrial Equipment Ltd., North Avenue, Otley, Yorks.**

BCE 4725 for further information

American-designed Butterfly Valves



A licence to manufacture U.S.-designed Rockwell butterfly valves for throttling, control and shut-off of air, gases, liquids and semi-solids has been secured by Cockburns. They are being manufactured in a range of sizes from 4 in. to 36 in. Different operating mechanisms are available to suit a variety of conditions. The valve body is generally constructed of cast iron, but can be supplied in other metals. Illustrated is a 12-in. size handwheel-operated Rockwell butterfly valve for service at 200 psig. **Cockburns Ltd., Cardonald, Glasgow, S.W.2.**

BCE 4726 for further information

Agitator Drives

The new range of Stockdale agitator drives are said to be the first gear units designed and manufactured in Great Britain for driving both vertical and side-entering, permanently-mounted agitators. The output shaft is about 50% larger in diameter than that of a typical standard gear unit for a given horse-power, and the bearing centres are more than 50% greater than those on a standard gearbox. The drive therefore, can be direct coupled to an agitator shaft of considerable unsupported length, without fear of either bending the gear shaft or overloading the bearings, Stockdale point out. The drives are suitable for installation on tanks, vats and closed pressure vessels. When used for open tanks, the drive, together with the motor, is bolted to a bedplate secured to beams placed across the top of the tank. The agitator shaft can be coupled directly to the output shaft of the drive, and bottom steady bearings need not be used, even on tanks up to 20 ft deep, when the complete agitator is properly engineered. For closed pressure vessels, the drives can be supplied complete with an integral flange mount incorporating a stuffing box or mechanical seal. **Stockdale Engineering Ltd., London Road South, Poynton, Ches.**

BCE 4727 for further information

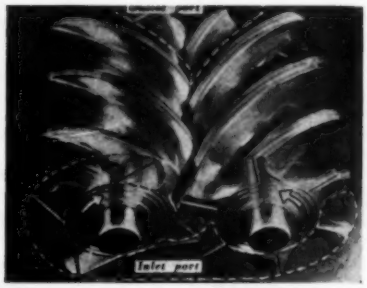
Fume-absorption Unit

One of Hathernware's latest products is their stoneware fume-absorption unit for industrial fumes and gases. It is described as a self-contained plant requiring small space and consisting of an absorption tower, ejector, pump and liquor tank. The tower is supported above the tank and is arranged with the bottom immersed in the liquor, forming a seal. A liquid-operated swirl-type stoneware ejector draws the fumes up the tower, and the stoneware pump actuates the ejector and re-circulates liquor in the tower. Liquor from the tank is returned either down the tower or from the tail pipe of the ejector, and can be readily checked to maintain its efficiency for absorbing the fume. When it is spent, the liquor can be drained off after neutralising to the required degree. The tower ejector, piping and valves are treated externally with resin-bonded glass fibre by the company's Fibresin armouring process. The unit is available in three sizes handling a range of fumes from 52-104 cfm. **Hathernware Ltd., Loughborough, Leics.**

BCE 4728 for further information

Screw Rotary Compressors

Screw-type rotary compressors of recent Swedish design, and delivering compressed air, oil-free, in capacities of 5500, 8100 and 16,000 cfm against a working pressure of 100 psi are available in Britain from Atlas Copco (Great



Britain). They are constructed to run at speeds of the order of 3000 rpm. **Atlas Copco (Great Britain) Ltd., Beresford Avenue, Wembley, Middx.**

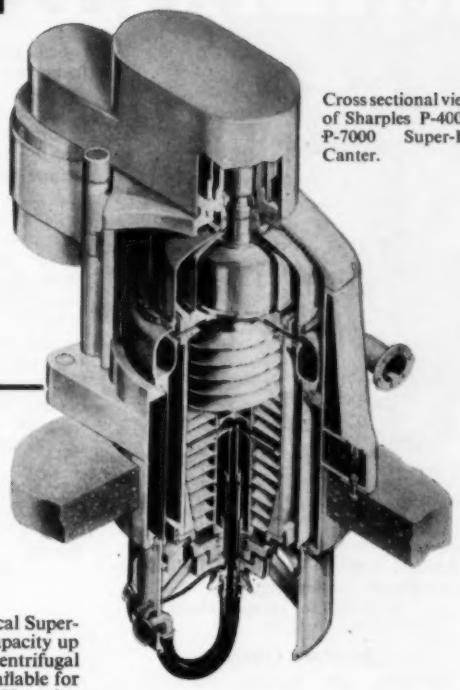
BCE 4729 for further information

Plastics Fine-adjustment Valve

A fine-adjustment valve in plastics, which has been supplied for some time for naval use, is now being introduced to industry by Chemical Pipe & Vessel. It is available in high-density polythene, rigid P.V.C., and Fluon (P.T.F.E.) in pipe sizes of ¼, ½, ¾ and 1 in. at present. The valve is fitted with a Fluon seat and has a maximum operating temperature of 65°C or more depending on the material of construction of the body. The company is willing to make

8 new Sharples centrifuges

Make the Sharples range still more comprehensive



Cross sectional view of Sharples P-4000 P-7000 Super-D-Canter.

For years Sharples have offered the widest range of centrifuges. Now come no less than 8 new models. This means a still more impressive range which extends still further the scope of service that we can offer on all separational problems.

1 **MODEL P-600** A new cylindrical bowl pilot scale horizontal type Super-D-Canter with a 6″ x 14″ bowl—a larger version of the already popular P-400 Model.

2 **MODEL P-3000** A cylindrical long bowl horizontal Super-D-Canter extending the range of the P-1000 and P-2000 series. This unit has a clarifying capacity of up to four times that of the P-2000.

3 **MODEL P-4000** A completely new vertical type Super-D-Canter of large liquid throughput capacity, having a centrifugal force of 3100 x g. Designs available for operation at pressures up to 150 p.s.i.g.

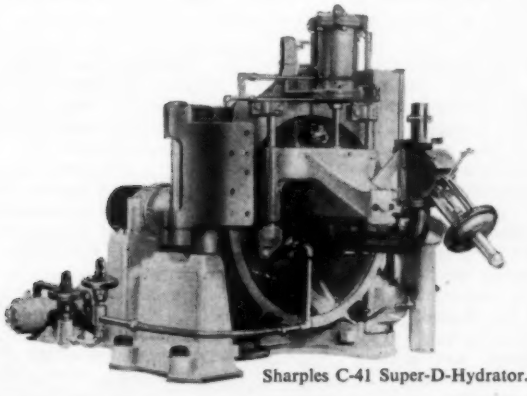
4 **MODEL P-7000** A larger vertical Super-D-Canter of solids handling capacity up to 10 tons per hour, with a centrifugal force of 1650 x g. Designs available for operation at pressures up to 150 p.s.i.g.

5 **MODEL C-41** A new high capacity perforate basket centrifuge of the Super-D-Hydrator range. Solids production capacity from 2-4 times that of the already well known model C-27 Super-D-Hydrator.

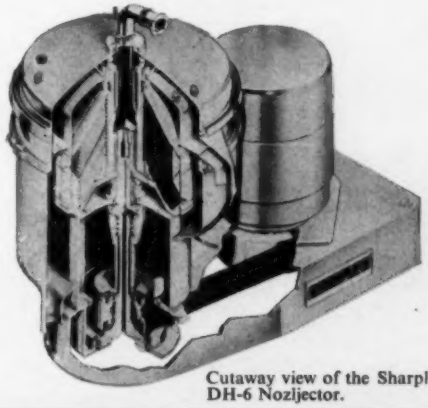
6 **MODEL DH-5** A new high capacity nozzle centrifuge having a liquid throughput of approximately twice that of the familiar DH-3 Nozljector. Designs available for operation at pressures up to 150 p.s.i.g.

7 **MODEL DH-6** The largest nozzle machine at present in our range, with a capacity of approximately 4 times that of the DH-3 Nozljector. Designs available for operating at pressures up to 150 p.s.i.g. The largest capacity nozzle centrifuge in the world !

8 **MODEL K-8** A pilot-scale Super Classifier for operation at feed rates of up to 250 lbs. an hour of dry powder. Suitable for test plant and for small scale production classification operations. Cut range identical with Super Classifier models K-16 and K-27.



Sharples C-41 Super-D-Hydrator.



Cutaway view of the Sharples DH-6 Nozljector.

Please let us have details of your separation or classification problem —we shall be pleased to submit our UNBIASED recommendations.

SHARPLES

SHARPLES CENTRIFUGES LTD · TOWER WORKS · DOMAN ROAD · CAMBERLEY · SURREY · *Tele: CAMberley 2601*

PLANT EQUIPMENT NEWS

"specials" such as steel-encased models. **Chemical Pipe & Vessel Co. Ltd., Godstone Road, Kenley, Surrey.**

BCE 4730 for further information

Gyratory Crusher

Babbitless are making available in Britain their gyratory crusher which has been in use on the Continent for a number of years and which, they point out, is distinguished by requiring no oil lubrication, the machine being fitted with grease-packed bearings. The range of models require power varying from 10 to 600 hp. **Babbitless Co. Ltd., 121 Victoria Street, London, S.W.1.**

BCE 4731 for further information

Tractor Shovel

Recently introduced by Michigan (Great Britain) is the 275A tractor shovel —the largest machine of its type built in Great Britain, they claim. Powered by a 265-hp diesel motor, it has a capacity of 22,000 lb., and is available with buckets with capacities of 4-8 cu. yd. All Michigan equipment of corresponding

capacities utilises the same power shift transmission, torque converters and axles and engines. **Michigan (Great Britain) Ltd., 3 Charles II Street, St. James's Square, London, S.W.1.**

BCE 4732 for further information

Solvents Still

Schlegel DE distillation units for inflammable solvents are being made available in the United Kingdom and most of the Commonwealth by Liquid Systems Ltd., sole agents for those areas, and the company are expecting to manufacture the equipment in Britain in the near future. The units, of West German design, are available in two sizes. The 200 model comprises a distilling chamber of 44 gals, capacity fitted with a water-cooled condenser. Control can be manual or automatic when the heating is by saturated steam at 45 psig or superheated steam, but is automatic only with the alternative electrical heating. A smaller model, the 30, is electrically heated, has a capacity of 6½ gals. and is suitable for liquids with the boiling range 40-200°C. The thermostat automatically switches off the electricity supply when the liquid has been distilled. **Liquid Systems Ltd., Norwich Union House, Wellesley Road, Croydon, Surrey.**

BCE 4733 for further information

Tote materials-handling bins (by Pressoturn, Ltd., Leamington Spa,) in use at the Slough factory of Aspro Ltd.

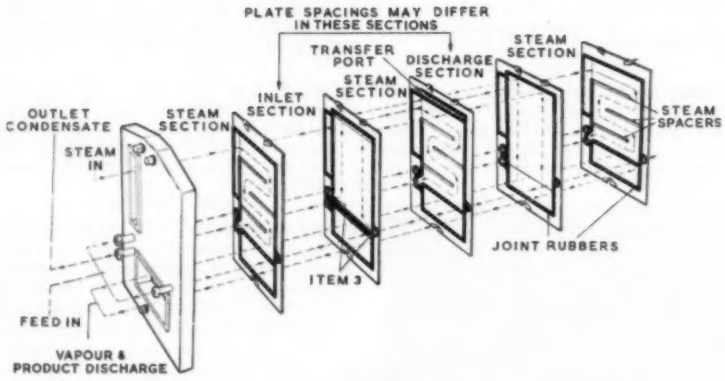
BCE 4734 for further information

Land Use of Marine Equipment

Megator marine pressure-system equipment has been used in a special industrial application just completed—the provision of a constant water supply for the hydraulic operation of salt valves at the works of Middlewich Salt Co. The equipment comprises pumps, pressure vessel, pressure switches, automatic starter and selector switch. **Megator Pumps & Compressors Ltd., 43 Berkeley Square, London, W.1.**

BCE 4735 for further information

Plate Evaporator



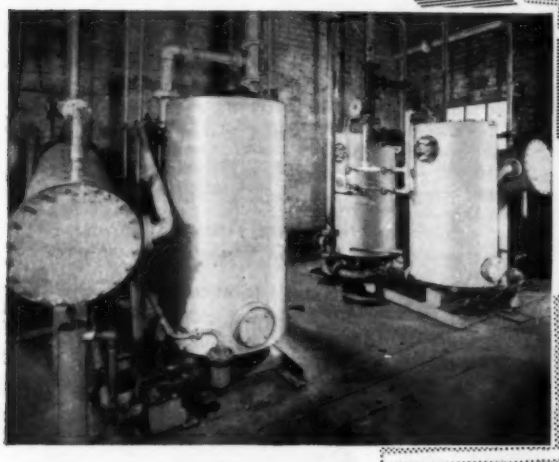
Ã.P.V. have produced an evaporator of novel design which operates on the climbing and falling film principle, using plates in an arrangement basically similar to that of the plate heat exchanger. The plates, gasketed and held together in a frame, replace the calandria of a conventional evaporator. Also the plant operates on a horizontal axis, an arrangement that enables its height to be kept small. Feed, entering the base of the inlet section at a controlled rate, boils on contact with the heated plates and rises to the top, where it transfers to the falling-film discharge section and boiling continues. The concentrated product and vapour are separated centrifugally. In a single-effect unit the product is withdrawn and the vapour removed to a condenser. Condensate from the steam side is also pumped from the machine and returned for boiler feed make-up.

Considerable steam economy is obtained by using double-effect evaporation. For this, preheated feed enters the first effect through an automatic flow controller and is boiled under vacuum by steam at about atmospheric pressure. The product is then pumped into the second effect, where it is boiled at higher vacuum by the condensing vapours from the first separator. Further concentration takes place, the resulting vapour being withdrawn from a second separator to the condenser. Generally, all parts of the evaporator in contact with the product are of stainless steel where the plant is used for processing potable liquids and food. Other materials of construction may be used, however. The following figures indicate some of the duties that have been carried out at production rates by the evaporator: whole milk, 12-50% T.S.; skim milk, 9-46% T.S.; whey, 6-37% T.S.; apple juice, 10-65% T.S.; apple pectin, 1-7% T.S. **The A.P.V. Co. Ltd., Manor Royal, Crawley, Sussex.**

BCE 4736 for further information

BCE 4569 for further information

Drying Hydrogen for Carbide Tools



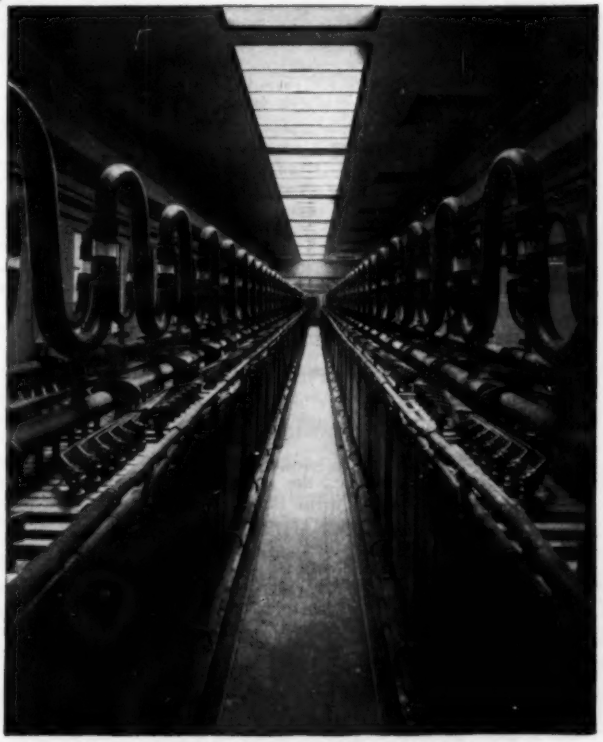
In the manufacture of Prolite tungsten-carbide tools, Murex Limited use Birlec adsorption dryers to remove water vapour from their electrolytic hydrogen supply.

The hydrogen is dried to a dew-point of minus 70°C for use in the reduction and sintering furnaces and the high quality of the product depends on the stringent moisture control.

Birlec moisture adsorbers are available in a range of standard sizes for varied industrial applications including the drying of compressed air and the dehumidification of factories and stores.

Illustration above:—
Birlec adsorbers for hydrogen drying.

Illustration right:—
Electrolytic hydrogen plant at Murex Limited.



BIRLEC ADSORPTION DRYERS
DRY AIR & GASES

DRYER DIVISION OF

BIRLEC LIMITED
An A.E.I. Company

ERDINGTON · BIRMINGHAM 24

LONDON SHEFFIELD · GLASGOW · NEWCASTLE-ON-TYNE

PLANT EQUIPMENT NEWS

Hammermill and Mixer

A combined hammermill and mixer for grain is one of the latest products of Wolseley Engineering. It can be converted also to a small grain drier without structural alteration, when it is automatic in operation and can be left running day and night. **Wolseley Engineering Ltd., Electric Avenue, Witton, Birmingham, 6.**

BCE 4737 for further information

INSTRUMENTS

Portable Gas Flow Recorder

The Arkon 58 portable gas flow recorder is designed to give an accurate record of gas flow in mains from 4-in. diameter upwards. Readings can be obtained at any number of points in mains of varying sizes. The gas does not have to be shut off and spot tests can be freely carried out whenever and wherever required. To take a reading the main is drilled and tapped 1 in. gas, a straight pitot tube is inserted and the gas flow recorded in cu. ft. per hr. After the test is completed the pitot tube is removed and replaced by a standard 1-in. gas plug, so that future tests can be easily repeated at the same point if desired. **Walker, Crosweller & Co. Ltd., Cheltenham.**

BCE 4738 for further information

Continuous Colorimetric Analysis

Quality control of plant streams by a series of rapid automatic colorimetric analyses is the purpose for which the Technicon Autoanalyser has been designed. Already in use for some time in the U.S.A., it is now being manufactured in Great Britain by a subsidiary of the originators, Technicon International, New York. A development of equipment devised for undertaking continuous examinations of biological fluids, it consists of a number of units which can be connected in a variety of ways to serve various requirements. The first is the sampler. For continuous sampling of a single-process stream that can be sampled directly through permanently connected tubing, this, however, can be dispensed with. If the same component is to be controlled in several streams, an automatic programmer is used to switch the input from various sample tubes to the analyser.

The second component is a patented peristaltic pump that meters the sample and reagents and drives them through flexible tubing to the other units. The pump handles up to eight tubes. "Slugs" of air are drawn in which separate slugs of liquid to prevent back-mixing of the samples and to keep the inner surface of the tubing scrubbed clean.

Samples and reagents are mixed by passing them through a horizontal helical glass tube. The desired component is then separated by dialysis. For reactions that require elevated temperatures (either before or after dialysis), the stream is passed through a coil immersed in a constant-temperature bath. The length of the coil and the flow rate of the sample determine the duration of the reaction. The final stage is the colorimetry. The colorimeter with a balanced-bridge system, compares the sample with a control standard and feeds a signal to the recorder. Where automatic feed-back control of the process is required, this signal can be fed to a servo mechanism or other regulating unit. Analyses can be undertaken, for example, at 1-, 1½ or 3-minute intervals. **Technicon Instrument Co. Ltd., 26 Warwick Road, London, S.W.5.**

BCE 4739 for further information

Deionisation System

Paterson are producing Solobed deionisation equipment in a capacity of 20 gal. an hour. **The Paterson Engineering Co. Ltd., 129 Kingsway, London, W.C.2.**

BCE 4740 for further information

Versatile Manometer

A manometer which can be simply and quickly arranged for flush panel, wall mounting or, with special stand, for laboratory bench work has been developed by Refinery Equipment & Speciality Co. The instrument is intended for the measurement of pressure, differential pressures and levels at system pressures up to 100 psig, and each is tested to 200 psig. Special features of the equipment include the provision of two line isolating valves and one equalising valve, shock-proof construction and a simple system for filling and venting the measuring fluid used, it is pointed out. Three standard instruments are available with scales of 6 in., 12 in. and 24 in. or of 15 cm., 30 cm. and 60 cm. and 0-100 sq. root. The cast-aluminium case is provided with two safety features—a transparent, plastic front and an adequate drainage and vent hole. **Refinery Equipment & Speciality Co. Ltd., Valley Works, Monton Road, Eccles, Manchester.**

BCE 4741 for further niformation

Chlorinator in Plastic

The components of the CE chlorinator are housed in a fibre-glass cabinet, and as far as possible plastic materials are used in the instrument's construction. **Chlorination Equipment Ltd., 129 Kingsway, London, W.C.2.**

BCE 4742 for further information

Moisture Meter

The new Shaw recording hygrometer gives full-scale deflection for the readings of 5% R.H. or less and provides warning of any increase in humidity in less than one second. Because of its long stability characteristics, no knobs or controls are fitted. The sensing of moisture is carried out by a new type of small variable capacitance element, an improved version of that used with the first Shaw hygrometer announced recently. An element for use in industrial driers at temperatures up to 150°C is available. **Shaw Moisture Meters, 31 Market Street, Bradford.**

BCE 4743 for further information

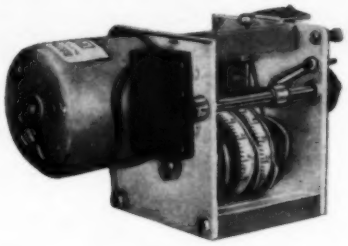
Digital Counter

Langham Thompson's new digital counter is available in several forms to cater for different applications. It can also be supplied in a single form combining all of the variations, and two remote indicators may be fitted to it. An accuracy of ± 1 count is claimed for the instrument, available as a tachometer and as a counter for random pulses up to 10 kcs. **J. Langham Thompson Ltd., Springland Laboratories, Bushey Heath, Herts.**

BCE 4744 for further information

Interval Timer

ElRemCo are marketing a miniature automatic multiple-circuit, multiple-interval synchronous timer, type AMS.



It consists essentially of an electromagnetically operated clutch, continuously-adjustable calibrated time setting dials with a snap-action change-over switch, and a miniature synchronous motor. The overall dimensions are 2¾ × 3½ × 6½ in. Standard time ranges vary from 0-30 seconds to 0-48 hours. **Electrical Remote Control Co. Ltd., Elremco Works, Harlow New Town, Essex.**

BCE 4745 for further information

ELECTRONIC COMPUTERS

NOTES ON A SELECTION of equipment shown at the recent Electronic Computer Exhibition at Olympia London (see also BRITISH CHEMICAL ENGINEERING, 1959, **4**, 31).

General-purpose Digital Computer

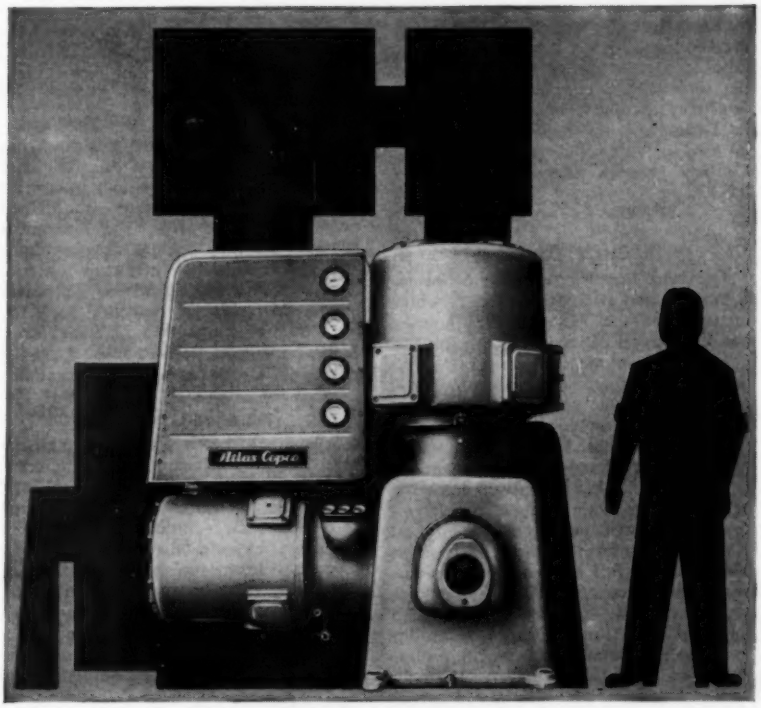
The new Elliott 802 digital computer is a general-purpose machine designed

BCE 4670 for further information

New Compressor Design

GIVES OUTSTANDING SPACE SAVING WITH REDUCED RUNNING COSTS

The Atlas Copco ER6 is a new stationary compressor which uses fundamental improvements in design to achieve remarkable results in performance and efficiency. The illustration shows the size of the ER6 compared with a conventional compressor of similar output: yet this extraordinary saving in space is achieved with *added* efficiency and economy, and with the same reliability of operation, which has characterised Atlas Copco compressors for 50 years.



Economy of operation

The specific power consumption for the ER6 is 10-15% lower than for most machines of this capacity range on the market. At 4,000 hours running time per year this means an *annual power saving of up to* £360.

In addition the cooling water consumption of the ER6 is very low because of the special design of the intercooler, amounting to only 440 gallons per hour at 60°F. This is less than half the quantity needed for the majority of other similar air compressors.

Economy of installation

The ER6 requires an exceptionally small amount of floor space for its capacity. This reduces the cost of foundation and erection, especially with the use of a flange-mounted motor.

Erection and alignment can be simplified by using a base frame which can be delivered as extra equipment. The balance is so good that the ER6 can be mounted on a skid frame, which does not require a concrete foundation. Skid frame mounting is especially advantageous for contractors and makes it possible for the compressors to be moved easily and at low cost from one site to another.

The ER6 is equipped with an oil pressure control device and cooling water gauges together with a full set of instruments for visual control.

PRINCIPAL DATA

Maximum pressure in psi	Speed in rpm	Low-pressure piston displacement in cfm	Free air delivered at 100 psi in cfm	Cooling water required at 60°F approx in galls/hour	Weight in pounds
125	485	1,300	1,075	440	6,600

A complete range of compressed air equipment

Atlas Copco manufactures portable and stationary compressors, rock-drilling equipment, loaders, pneumatic tools and paint-spraying equipment. Sold and serviced by companies or agents in ninety countries throughout the world.

Atlas Copco PUTS COMPRESSED AIR TO WORK FOR THE WORLD

Contact your local company or agent or write to Atlas Copco AB, Stockholm 1, Sweden

C.10-1 G.B.

PLANT EQUIPMENT NEWS

for work on problems varying from business arithmetic to the solution of mathematical problems and the control of industrial processes. The basic logical elements, which are standard, consist of a magnetic core, a resistor and a transistor, with printed-circuit plug-in boards. Only three keys are used to control the operations, and the computer is described as being little larger than a desk. Standard input is by five-hole punched paper tape at speeds of up to 170 characters per second. The computer is suited for time-sharing operations and another of its advantages, the makers point out, is its low cost. **Elliott Bros. (London) Ltd., Century Works, Lewisham, London, S.E.13.**

BCE 4746 for further information

Industrial Data Set

The new 609 Pannellit industrial information and computing system, which incorporates the Elliott 802 computer, has a scanning capacity of 600 points a minute. It can measure and store raw data, intermediate and reduced data; carry out periodic calculations based on a stored programme, and present information in digital form by automatic printer, punched tape or card, magnetic tape, visual display or any combination of these. The output may also reset individual control units on the process plant. The machine's discrimination is 4000 parts of full scale or 5 microvolts, and its accuracy of digitising ±5 microvolts or 0.025%. A set has been supplied to the U.K. Atomic Energy Authority to provide a scan of 600 reactor points measured by thermocouples. **Pannellit Ltd., Dudden Hill Lane, London, N.W.10.**

BCE 4747 forf urther information

Versatile Analogue Equipment

The new K.A.E. I analogue equipment was designed and built in the Analogue Equipment Laboratories of English Electric, Kidsgrove, Stoke-on-Trent, to assist the company's engineers in the solution of servo problems, but its versatility enables it to handle a wide variety of analogue problems. A system of shorting plugs and interconnections used in conjunction with metering switches and potentiometers allows problem parameters to be quickly changed and the dynamic characteristics of the particular control system under study to be examined speedily. **English Electric Co. Ltd., Marconi House, Strand, London, W.C.2.**

BCE 4748 for further information

General-purpose Transistor Machine

The 7070 data-processing equipment has been designed by IBM as a general-purpose all-transistor machine suitable for scientific and commercial uses. It is based on the "building block" principle and provides "floating" decimal operation and parallel read-out. It makes available 99 index registers for programme modifications and over 150 basic operation codes. The primary store is 5000 or 10,000 words of magnetic core storage. Backing storage is provided by magnetic tapes and by random access disc storage units. One of its main features, the manufacturers point out, is "priority processing" by which two unrelated programmes may be run simultaneously. **IBM (United Kingdom) Ltd., 101 Wigmore Street, London, W.1.**

BCE 4749 for further information

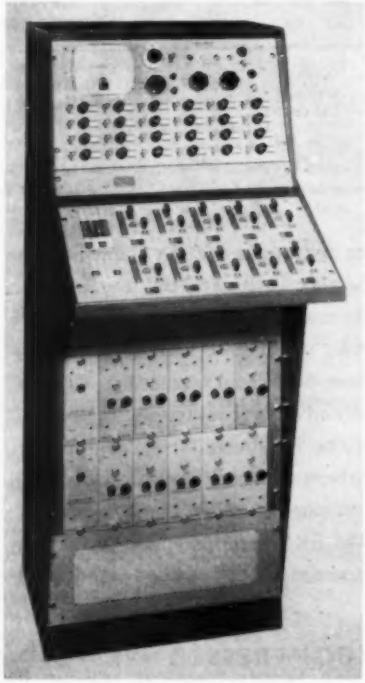
Control System Analyser

Shorts' control-system analyser has been designed to allow the response curve of a complete open-loop system or of components or both to be obtained quickly and accurately. The instrument contains in one cabinet the oscillator and voltmeter, which make up the analyser, and in a second cabinet the power units. Amplitude is controlled to ±1% by a built-in control circuit. **Short Bros. & Harland Ltd., Belfast.**

BCE 4750 for further information

Analogue Computers

Solartron's new Minispace analogue computer is a self-contained unit, comprising ten drift-corrected DC amplifiers. Non-linear elements are incorporated and expansion facilities provided. Each amplifier can be used for summing, sign reversing, integration or simulation of a transfer function over a wide range. Used in conjunction with the company's Servo multiplier TJ 725, which can function as a multiplier, resolver or non-linear function generator, more complex problems can be tackled, Solartron point out. Soon to be made available is the Space 48, an analogue computer incorporating 48 operational amplifiers.



The latest Solartron transfer-function measuring equipment, the PRA, is designed to make accurate measurements of slow and medium-speed dynamic systems, for example nuclear-reactor heat exchangers and chemical plant under severe non-linear conditions. **The Solartron Electronic Group Ltd., Thames Ditton, Surrey.**

BCE 4751 for further information

Transistor Process-control Prototype

A transistor electronic digital computer, designed to provide fully automatic control of industrial processes, is being developed by Ferranti Ltd. It has reached the prototype stage and the first production models are expected to be available in 1960. No thermionic valves are used in its circuits and the equipment will measure only about 4 × 4 × 2 ft. An experimental model has controlled a machine simulating a plant process for more than 12 months without component failure. Babcock & Wilcox Ltd. and their associates, Bailey Meters & Controls Ltd., are investigating the feasibility of using the computer for the control of boilers during start-up and shut-down.

Ferranti's new Perseus data-processing system, designed specifically for administrative work, has applications in stock control and production, and in "industrial mathematics". **Ferranti Ltd., Hollinwood, Lancs.**

BCE 4752 for further information

Mechanical Analogue Equipment

Mechanical analogue - computing equipment capable of integration, summation, multiplication and division and having facilities for dealing with non-linear terms are available from Air Trainers Link. The makers suggest that various combinations of the equipment, all of which was developed for computing aircraft motion, have useful applications in chemical engineering problems such as integrating flow rates over long periods. The company also manufacture special-purpose electronic computers and simulators. **Air Trainers Link Ltd., Bicester Road, Aylesbury, Bucks.**

BCE 4753 for further information

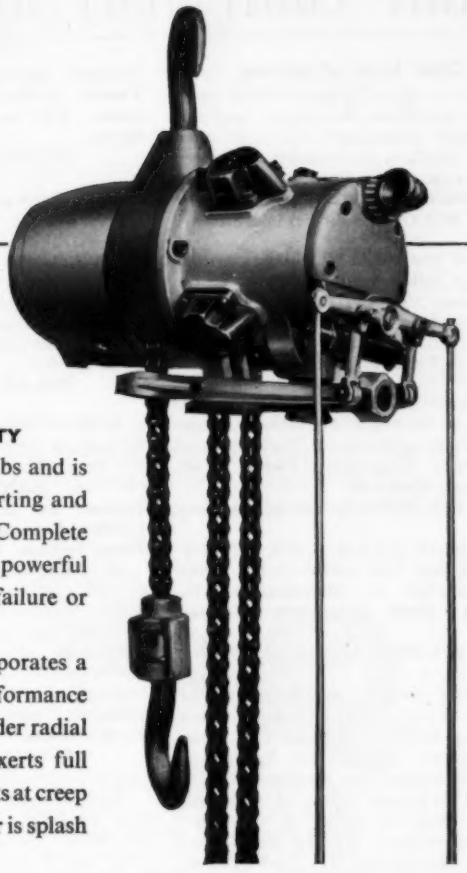
The circuitry of the Metrovick 1010 business-data processing system has been designed with transistors and no thermionic valves. The machines programme scanning allows two or more programmes to be run concurrently. **Metropolitan-Vickers Electrical Co. Ltd., Trafford Park, Manchester, 17.**

BCE 4754 for further information

Greater flexibility and ease in use are advantages claimed for the latest model of Fairey's multi-purpose analogue computer. The computing panel houses 12 standard DC operational amplifiers in the form of a thin slab which plug into the back of the panel. **The Fairey Aviation Co. Ltd., Heston, Middx.**

BCE 4755 for further information

NEW LIGHTWEIGHT AIR MOTOR HOIST FROM ATLAS COPCO



The well-known Atlas Copco MLT range includes air motor hoists ranging up to 10 tons capacity. The newest addition to the range is the smallest and lightest of all—the MLT 11 KR, with a lifting capacity of a ¼ ton.

PERFECTLY CONTROLLED SPEED AND COMPLETE SAFETY

Despite its high capacity the MLT 11 KR weighs only 40 lbs and is easily portable. The 4-cylinder air motor gives smooth starting and perfectly controlled speed from creep to 35 feet per minute. Complete safety is assured by the upper and lower limit stops and a powerful automatic brake which prevents racing in case of supply failure or when throttle is closed.

The MLT 11 KR is equipped with roller chain and incorporates a number of design features which contribute to its high performance and the safety and economy of its operation. The four cylinder radial type piston air motor has precision made pistons, and exerts full torque regardless of throttle opening, permitting smooth starts at creep speed. All shafts are provided with roller bearings. The motor is splash lubricated.

PRINCIPAL DATA	Capacity at 85 psi	Operating speed at full load: lifting	lowering	Standard height of lift	Air consumption at full load	Weight	Hose
	¼ ton	35 ft/min	100 ft/min	10 ft	0.8 cu ft/ft	40 lb	3/8"

WIDE FIELD OF APPLICATION

The fine throttle control permits effortless and safe lifting, lowering and positioning of loads. For this reason the new hoist is already in demand for servicing machine tools and assembly lines, in foundries, press rooms and shipping rooms, etc. It lends itself particularly well for work in pickling plants and other acid or salt-laden atmospheres, or where spark hazards must be eliminated. On shipboard this light portable hoist is invaluable for speeding up all kinds of repair and maintenance work.

A COMPLETE RANGE OF COMPRESSED AIR EQUIPMENT

Atlas Copco manufactures portable and stationary compressors, rock-drilling equipment, loaders, pneumatic tools and paint-spraying equipment. Sold and serviced by companies or agents in ninety countries throughout the world.

Atlas Copco PUTS COMPRESSED AIR TO WORK FOR THE WORLD

Contact your local company or agent or write to Atlas Copco AB, Stockholm 1, Sweden, or Atlas Copco (Great Britain) Limited, Beresford Avenue. Wembley, Middlesex

T.31

PLANT EQUIPMENT NEWS

Other Items of Interest

A new range of remote-control push-button equipment, the Dupar unit system, which makes use of a large number of standard components, has been made available by **Dewhurst & Partner Ltd., Inverness Works, Hounslow.**

BCE 4756 for further information

A new assembly of ball-bearing slewing rings suitable for loading machines are being produced by **Roballo Engineering Co. Ltd., 43 Dover Street, London, W.1.**

BCE 4757 for further information

Goodyear self-priming pumps are shortly to be made available in stainless steel in addition to Mechanite and aluminium. **Goodyear Pumps Ltd., Camborne, Cornwall.**

BCE 4758 for further information

A metal-spraying unit, trolley-mounted, has been added to the equipment supplied by **Metallisation Ltd., Barclays Bank Chambers, Dudley, Worcs.**

BCE 4759 for further information

A 10-lb. carbon dioxide fire extinguisher, model 1510, has been introduced by Nu-Swift to supersede model 1210. Mainly intended for fighting inflammable-liquid and electrical fires, it has a 15-ft range compared with only 8 ft for the old model. A redesigned nozzle provides a doubled fire-fighting capacity, the makers say. **Nu-Swift Ltd., Elland, Yorks.**

BCE 4760 for further information

New Publications

Three new leaflets have been issued by Knitmesh respectively outlining the use and specification of their knitted-wire mesh product; describing its use in demisters, mist eliminators and separators and describing Knitmesh multifil, a packing material for small and medium-size fractionation columns. **The Hydronyl Syndicate Ltd., 14 Gloucester Road, London, S.W.7.**

BCE 4761 for further information

A 15-page booklet described as a brief introduction to the facilities provided by Yarsley Testing Laboratories is the latest publication from that independent laboratory. The booklet relates how the laboratory has been built up over the past 25 years to provide a range of specialised apparatus operated by experts, and to make available testing facilities for industry in general and for the plastics and related industries in particular. The properties which the laboratories have facilities to assess include electrical, thermal, optical, mechanical and physico-chemical. The testing laboratories are associated with Yarsley Research Laboratories, formerly known as Dr. V. E. Yarsley (Research Laboratories) Ltd., which grew out of Dr. Yarsley's personal consulting practice. **Yarsley Testing Laboratories Ltd., Oaklands, Clayton Road, Chessington, Surrey.**

BCE 4762 for further information

Apex Construction have issued a catalogue of their equipment for pharmaceutical, food and chemical processes and other industries, including machinery for tableting, mixing, blending, comminuting, granulating and size reducing, drying, evaporating and pumping. **Apex Construction Ltd., 15 Soho Square, London, W.1.**

BCE 4763 for further information

A list of titles of programmes being worked on Ferranti's Mercury computer has been issued to inaugurate a scheme for the interchange of information between the users of that computer. **London Computer Centre, 21 Portland Place, London, W.1.**

BCE 4764 for further information

The Magnesium Industry Council has published an illustrated 28-page book on the scope of magnesium castings of various kinds, of sheet, extrusions and forgings of the metal. **The Magnesium Industry Council, Dickens House, 15 Took's Court, London, E.C.4.**

BCE 4765 for further information

Recrystallised alumina, tubes, sheaths and insulators are among the products for which specifications are given in a new leaflet from **Morgan Refractories Ltd., Neston, Wirral, Cheshire.**

BCE 4766 for further information

The variety and specifications of Doulton chemical and industrial stoneware and plant (which includes filters, grinding equipment, towers and accessories) are indicated in a 24-page illustrated book from **Doulton Industrial Porcelains Ltd., Wilnecote Works, nr. Tamworth, Staffs.**

BCE 4767 for further information

A leaflet is available describing the glassless thermometer, type V.B., made by **Buchanan Bros. Ltd., Clyde Instrument Works, Commerce Street, Glasgow, C.5.**

BCE 4768 for further information

Specifications and sizes of the Wet Deduster Series MG of Dallow Lambert are published in folder No. 56 by **Dallow Lambert & Co. Ltd., Thurmaston, Leicester.**

BCE 4769 for further information

Simon-Carves have published a 14-page booklet on the OT forced-circulation boilers. The information, which is illustrated, describes the principle of design of the boilers, their construction, operation and control. **Simon-Carves Ltd., Cheadle Heath, Stockport, Cheshire.**

BCE 4770 for further information

New booklets from International Combustion are devoted to the Tyler sample splitter and reducer and the Rotap testing sieve shaker. **International Combustion Products Ltd., 19 Woburn Place, London, W.C.1.**

BCE 4771 for further information

A 53-page book liberally illustrated with pictures in colour has been published by BP to record the story of the development and work to date of their Kent refinery. Strikingly laid out, the book describes the various stages in the construction of the plant, mentions the setback it received during the East coast floods, and reminds its readers of the visit of the Queen in 1955. The last half ot the publication is devoted to a semi-technical description of the processes involved in refining and this is helped by the provision of a simplified flow diagram of the refinery. The publishers state that the refinery has now almost doubled its original capacity and that the growing demand for oil products will cause the installation to be expanded further. **The British Petroleum Co. Ltd., Britannic House, Finsbury Circus, London, E.C.2.**

BCE 4772 for further information

A 28-page booklet illustrating the range of pumps made by Sigmund Pumps Ltd., and some of their applications in the field, is available from **Sigmund Pumps Ltd., Team Valley, Gateshead, 11.**

BCE 4773 for further information

The new Blencut vibratory feeders and conveyors for feeding materials at controlled rates over distances of inches to feet and in capacities from ounces to tons are described in a four-page leaflet from **Blending Machine Co. Ltd., Bond Street, Hockley, Birmingham, 19.**

BCE 4774 for further information

Carter Gears leaflet DFC/2 gives details and dimensions of their hydraulic relay speed control for "F"-type Carter hydraulic infinitely-variable-speed gears. **Carter Gears Ltd., Thornbury Road, Bradford, 3.**

BCE 4775 for further information

The relationship of the British Hydrocarbon Chemicals Ltd. to its associated companies and the work of those companies is the subject of a recently-published 28-page booklet in colour from B.H.C. A double-page diagram illustrates the arrangement of the plants at Grangemouth and the products derived from them. The descriptive matter on the plant, processes and uses of the products is on a general technical level. **British Hydrocarbon Chemicals Ltd., Devonshire House, Piccadilly, London, W.1.**

BCE 4776 for further information

Johnson, Matthey have produced a new publication, 1700 — Platinum Laboratory Apparatus, revising and combining the earlier booklets 1710 and 1720. **Johnson Matthey & Co. Ltd., 73 Hatton Garden, London, E.C.1.**

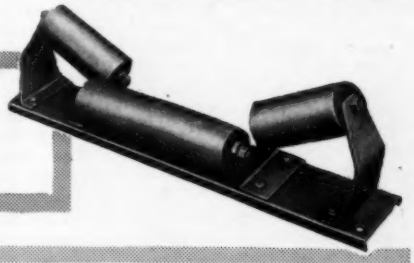
BCE 4777 for further information

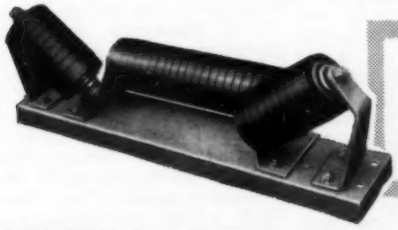
BCE 4672 for further information

Long Lived Idlers

Sutcliffe idlers ensure almost frictionless conveying with minimum maintenance. Grease packed for long life and designed to suit the most arduous conditions, Sutcliffe idlers increase belt life by providing a carefully proportioned trough to the belt for even weight distribution and tracking.

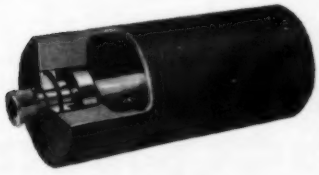
3 Pulley Fully Troughed Idlers used throughout the standard run of the conveyor. The trough of the idler is deepened at the loading point to provide a high degree of automatic centralisation of the load.





3 Pulley Impact Idlers. Three used at every loading point absorb the impact from heavy and sharp material, thus preventing damage to the belt. The cushioning effect is obtained by a series of rubber rings clamped endwise to present an unbroken surface to the belt.

Disc Type Return Rollers present a limited area to the belt, thus preventing deposit build up. These rollers are especially successful when sticky materials, such as superphosphate, are handled.



Cast Iron Idlers. This cut away section shows the unique piston ring seal which provides complete protection for the bearings. This idler is specifically designed for handling materials where abrasion or corrosion must be resisted.

Sutcliffe

MAKERS OF BRITAIN'S BUSIEST IDLERS

RICHARD SUTCLIFFE LTD · HORBURY · WAKEFIELD · ENGLAND

London Office: 28-29 Savile Row, W.I.

dm RS.15

Month's News in Brief

Unesco's £½ million

Unesco will devote more than $2½ million (£½ million) in 1959-60 to the execution of its programme in the field ot the natural sciences and in scientific research on arid lands. Though this sum is not enough for all the projects that might be undertaken in these fields, it will provide for many important activities which have just been considered by the Programme Commission of the General Conference aided by a working group of scientists and specialists. Unesco's contribution to scientific research is to have bearing also on research on the humid tropical zone, cell biology, nuclear physics, new sources of energy and the numerical processing of information and electronic computation. The latter will be the subject of an important conference in 1959. Two new topics are being considered: research in cerebrology and exploration of extra-terrestrial space. When the working group took up the questions of contribution to research, it became interested in a project for a study of major research trends and of the dissemination and application of scientific knowledge for peaceful ends. This project was based on a draft resolution submitted by Australia to the United Nations' General Assembly, which adopted it and transmitted it to Unesco. As the project represents a new field of activity for Unesco, it is to be examined by the General Conference along with others not yet covered by the budget ceiling. Also listed for consideration by the General Conference, if financing is possible, are two projects that would complete the programme concerning scientific documentation: the improvement of documentation through the International Abstracting Board; and the preparation of a multilingual dictionary of water resources terminology.

International Symposium on Distillation

The Chemical Engineering Group of the Society of Chemical Industry and the Institution of Chemical Engineers propose to hold in the Spring of 1960 an international symposium on distillation.

The meeting will be held on three days with subjects as follows: *First day*—Fundamentals (theory); Morning session: Vapour-liquid equilibria; Afternoon session: Mass and heat transfer; *Second day*—Fundamentals (practice); Morning session: Hydrodynamics of distillation apparatus; Afternoon session: Prediction of plant efficiencies. *Third day*—Plant; Morning session: Comparative performance of tray columns; Afternoon session: Correlation of performance of packed and other columns.

The submission of papers for consideration for presentation is invited. Summaries should be sent to The Institution of Chemical Engineers, 16 Belgrave Square, London, S.W.1, before June 1, 1959 and manuscripts will be required not later than October 31, 1959.

F.B.R.A.M. Technical Panel

The Plant Lining Group of the Federation of British Rubber and Allied Manufacturers has set up a technical panel to consider the possibility of drawing up a code of practice for rubber and ebonite linings, which customers can specify at the time of ordering and thereafter rely on as a guarantee of quality in any work undertaken by members of the Group. Suggestions from designers and fabricators of chemical plant on points which a code of practice might usefully cover should be sent to the Director, Federation of British Rubber and Allied Manufacturers, 43 Bedford Square, London, W.C.1.

News Briefs

The Institute of Fuel announce that a summer meeting and conference on "Major Developments in Liquid Fuel Firing 1948-1959" will be held in Torquay from May 11-14, 1959. Details can be obtained from: The Institute of Fuel 18 Devonshire Street, Portland Place, London, W.1.

The four-year full-time course in chemical engineering at Loughborough College of Technology has been recognised by the National Council for Technological Awards as leading to the Diploma in Technology for a five-year period.

The Microbiology Group of the Society of Chemical Industry is arranging a symposium on Continuous Culture to be held at the Society's headquarters, 14 Belgrave Square, London, S.W.1, on Thursday and Friday, March 31 and April 1, 1960.

Private displays of interest to those engineers concerned with electrical control systems have been arranged by Londex Ltd., London. The company's range of relays, process timers, pressure switches, level controls, counters, etc., will be exhibited at the following centres. Coventry: The Craven Arms, High Street, January 12 and 13; Birmingham: The Engineering Centre, Stephenson Place, January 15 and 16; Bristol: Royal Hotel, College Green, February 2 and 3; and at Southampton: Royal Hotel Cumberland Place, February 5 and 6.

An agreement between Dow Chemical Co. and United States Borax Research Corp., a wholly owned subsidiary of United States Borax & Chemical Corp. (the operating company in the U.S.A. of Borax (Holdings) Ltd.), to engage in a joint venture to perfect an economic process for the manufacture of boron trichloride has been announced. Dow and U.S. Borax have both been engaged independently on research in this field.

Heather Filters Ltd. have moved their offices to 7 Kendall Place, Baker Street, London, W.1. Tel.: HUNter 1801.

Endecotts (Filters) Ltd. have acquired larger premises at Lombard Road, London, S.W.19. Tel.: LIBerty 8121/2.

Durham Raw Materials Ltd. announce that their Manchester office has moved to Canada House, 3 Chepstow Street, Oxford Street, Manchester, 1. Tel. CENtral 2683. Mr. Punton has been appointed as manager of the office.

Electrical Remote Control Co. Ltd. is holding an exhibition of electrical timing and automatic control equipment at the Birmingham Exchange and Engineering Centre, Stephenson Place, Birmingham, 2, on February 10 and 11 from 10 a.m. to 9 p.m. both days.

People in the News

Honours announced in the New Year List include: *Knights:* **Major-General C. A. L. Dunphie,** managing director, Vickers Ltd.; **R. P. Linstead,** Rector Imperial College of Science and Technology; **D. W. Logan,** Principal, University of London; **I. D. Lyle,** chairman, Tate & Lyle Ltd.; **E. J. Pode,** managing director, Steel Co. of Wales Ltd.; **K. T. Spencer,** chief scientist, Ministry of Power.

Order of Merit: **Earl Alexander of Tunis,** a director of Aluminium Ltd. and Aluminium (Canada) and chairman of Northern Aluminium Co. Ltd.

Order of St. Michael and St. George, C.M.G.: **C. Waite,** chairman and joint managing director, Consolidated Tin Smelters Ltd.

Order of the British Empire, C.B.E.: **S. E. Clotworthy,** managing director, Northern Aluminium Co. Ltd.; **M. Cook,** chairman, Metals Division, Imperial Chemical Industries Ltd.; **T. C. Finlayson,** chairman, Woodall-Duckham Ltd.; **P. T. Fletcher,** deputy managing director, Industrial Group Headquarters, Risley, Atomic Energy Authority; **R. J. Pinder,** managing director, Esso Petroleum Co. Ltd; **J. McW. Storey,** managing director, Dewrance & Co. Ltd. *O.B.E.:* **C. V. Hill,** lately refining adviser, British Petroleum Co. Ltd.; **P. W. Mummery,** senior principal scientist, Reactor Division, Atomic Energy Research Establishment, Harwell. *M.B.E.:* **R. J. Bracey,** lately head, Optics Department, British Scientific Instrument Research Association; **W. H. Dally,** chief engineer and supervisor, Aberthaw Cement Works, Glam.; **W. R. A. D. Moore,** reader in high polymer chemistry, Dept. of Chemical Technology, Bradford Institute of Technology; **C. Stamps,** shops superintendent, Dorman Long (Chemicals) Ltd.; **S. Wigglesworth,** safety and civil defence officer, I.C.I. (Dyestuffs) Huddersfield; *B.E.M.:* **J. Forster,** leading hand fitter, Alkali Division, I.C.I. (Northwich); **G. W. Nicholson,** valve shop foreman, Richardsons Westgarth (Hartlepool) Ltd.

Dr. T. Leadbetter Cottrell, at present personal assistant to Sir Ewart Smith, a deputy chairman of Imperial Chemical Industries Ltd., has been appointed Professor of Chemistry at Edinburgh University. He succeeds **Professor James P. Kendall,** who retires at the end of September 1959. Dr. Cottrell, who is 35, was educated at Edinburgh University and graduated B.Sc. with first-class honours in chemistry in 1943, and in 1952 gained

BCE 4673 for further information

There's never a gripe with a *Jenkinsons* PIPE

As every Chemical Engineer knows, there are pipes and PIPES.
Copper, Lead, Aluminium, Stainless Steel, Plastic and Monel Metal Pipes, in all sizes and shapes, and in combinations of any one metal with Homogeneous Lead Covering, provide a most varied programme from week to week at JENKINSONS.
From John O'Groats to the Middle East, JENKINSON Pipes are performing their task efficiently.
Call for PIPES by JENKINSONS.

COILS and PIPEWORK

IN LEAD, COPPER, PLASTICS, ALUMINIUM, STAINLESS STEEL.

HOMOGENEOUS AND FABRICATED LEADWORK

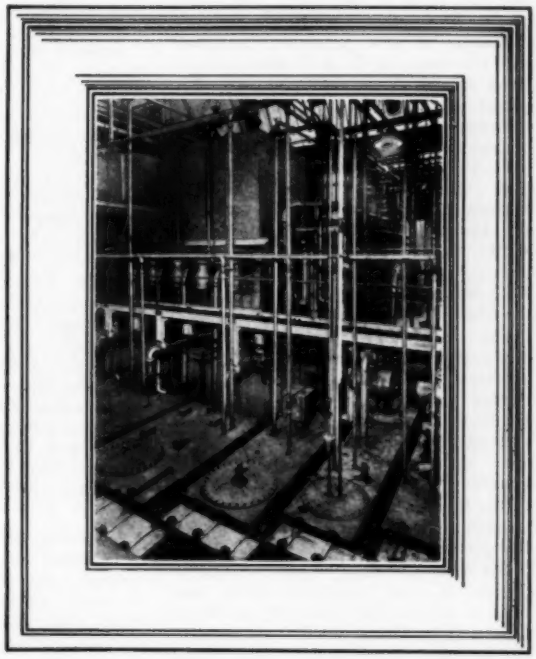
•

W. G. JENKINSON LTD.
ARUNDEL STREET; SHEFFIELD 1.
Phone 27438/9

BCE 4674 for further information

PORTRAIT OF A *Beauty*

ARTIST W·B·BAWN



The Modern Masters of

STEEL PLATE FABRICATION

especially of storage tanks for chemicals, are . . .

. . . conveniently at your service. We have over 100 years experience in the design and fabrication of this highly specialised equipment and are happy to work to customers own designs or to supply plans for complete installations or single tanks in the field of liquid handling.
Of course, we do not specialise alone in tanks and vessels but all types of chemical plant, condensers, evaporations, filters, duct work, etc. May we have your enquiry?

HELMSMAN PRODUCTS

W·B·BAWN
& COMPANY LIMITED

x

Byron Works, Blackhorse Lane, London, E.17. Telephone: LARkswood 4411/4

ALSO MANUFACTURERS OF "HELMSMAN" ROAD TANK BODIES AND STEEL EQUIPMENT

the Meldola Medal of the Royal Institute of Chemistry, awarded annually to the most promising chemist under 30 years of age.

Steele & Cowlishaw Ltd., Stoke-on-Trent, announce that **Mr. F. Limb**, O.B.E., has resigned from the position of managing director. **Mr. J. B. Capey**, previously director and general manager, succeeds Mr. Limb, who remains on the board of the company.

G. & J. Weir Holdings Ltd. is the new title for G. & J. Weir Ltd. The Cathcart trading undertaking has been transferred to a new subsidiary company with the name of G. & J. Weir Ltd., as given up by the parent company. The parent company operates as a holding company under the direction of the present board. The board of the new operating subsidiary company is as follows: **Hon. J. K. Weir** (chairman); **J. Russell Lang** (managing director); **J. W. Atwell** (deputy managing director); **A. C. Smith** (sales); **J. J. B. Young** (finance); **Gavin Milligan** (works); and **R. S. Silver** (technical). The secretary of the new company is **Mr. Harvey Waugh.**

The United Kingdom Atomic Energy Authority has appointed **Mr. L. Grainger** as Head of Metallurgy Division in the Authority's Research Group at Harwell. He is to succeed **Dr. H. M. Finniston,** who is being released by agreement to take up an appointment with the Nuclear Power Plant Co.

Mr. R. H. Mardell has been appointed London area sales manager for General Refractories Ltd.

Dr. A. J. Kesterton, at present superintendent of steel production of the steel division in the Steel Company of Wales Ltd., will be taking up the appointment of managing director of Davy British Oxygen Ltd. early this year.

Mr. R. J. de Vries has been appointed technical sales manager of Armour Chemical Industries Ltd., London.

It has been announced that the board of the newly-formed company of Birlec-Efco (Melting) Ltd., comprises: **P. Tinker** (chairman); **J. C. Howard** (managing director); **F. S. Leigh** (assistant managing director); **D. L. Campbell, J. H. Crossley, P. F. Hancock, J. A. Monks** and **T. G. Tanner.** The secretary of the company will be **J. C. Mantell.**

Mr. L. Ingham, formerly manager of the industrial sales division, has been appointed assistant sales manager of Chloride Batteries Ltd., London, S.W.1.

Obituaries

Prof. Wolfgang Pauli, Professor of Physics at the Federal Polytechnical High School, Zürich, died on December 15 at the age of 59. Born in Vienna, Pauli was one of the great theoretical physicists of his generation. His first and most important contribution to physics was in 1924. This was the generalisation that no two electrons could be in the same energy state—the "exclusion principle" as it has been called. There is no explanation of this principle, which in its general form was stated by Pauli. It is accommodated in the later treatment of electrons in terms of wave mechanics.

Mr. E. Hargrave, who was appointed home sales director of Associated Chemical Companies (Sales) Ltd., on the formation of the company in July, 1958, died on December 6 at the age of 44.

Meetings of the Month

The Institution of Chemical Engineers

January 20. *North-western Branch:* At the Blossoms Hotel, Chester. "Separation of Isotopes by Molecular Distillation", by P. T. Nettley. **7 p.m.**

January 29. *Scunthorpe Group: At the Grimsby College of Further Education, Nuns Corner, Grimsby.* "Design Data and Specification of Requirements, including Site Selection", by J. P. Asquith. **7.30 p.m.**

February 3. *Joint Meeting of the North-western Branch with Graduates and Students Centres:* At the Chemical Engineering Building, Manchester College of Science and Technology, Jackson Street, Manchester. "Effluent Disposal and Air Pollution". **3 p.m.**

February 7. *Midlands Branch:* At Birmingham College of Technology, Gosta Green, Birmingham. "Principles of Selecting Dimensional Systems and Units in Chemical Engineering", by A. Klinkenberg. **2.30 p.m.**

February 12. *At Church House, Westminster, London, S.W.1.* "Symposium on Mass Transfer". **9.30 a.m.**

Society of Chemical Industry

February 10. *Chemical Engineering Group:* At the Society of Chemical Industry, 14 Belgrave Square, London, S.W.1. "The Extraction of Thorium", by W. D. Jamrack, R. A. Wells and Dr. J. H. Buddery. **6 p.m.**

The Society of Instrument Technology

January 27. At Manson House, Portland Place, London, W.1. "Symposium on Flow Measurement". **5.30 p.m.**

February 16. *Cheltenham Section:* At the Rotunda, Cheltenham. "Instruments for Nuclear Reactors", by T. D. H. Andrews. **7.30 p.m.**

January 28. *Chester Section:* At the Grosvenor Museum, Grosvenor Street, Chester. "Electrical Weighing—Its Technique and Application", by K. J. Railler. **7 p.m.**

February 19. *East Midland Section:* At Nottingham and District Technical College, Shakespeare Street, Nottingham. "Data Collection and Processing", Solartron Industrial Controls Ltd. **6.30 p.m.**

February 6. *Fawley Section:* At Copthorne House, Fawley, Hants. "Laboratory and Industrial *p*H Measurements and Titrations", by G. Mattock. Time to be announced.

January 29. *Grangemouth Section:* At Leapark Hotel, Grangemouth. "Electronic Weighing", by K. J. Railler. **7 p.m.**

February 10. *Manchester Section:* At the "Manchester" Room, Central Library, St. Peter's Square, Manchester, 1. "A Contractor's Approach to Instrumentation", by J. Sheraton. **6.30 p.m.**

January 21. *Newcastle Section:* At King's College, Stephenson Buildings, Newcastle upon Tyne. "Applications of High-speed Strain-recording Equipment", by R. Kasler. **7 p.m.**

February 18. *Newcastle Section:* At King's College, Stephenson Buildings, Newcastle upon Tyne. "Variable Area Flowmeters", by F. C. Whalen. **7 p.m.**

February 27. *Scottish Section:* At the Scottish Building Centre, 425 Sauchiehall Street, Glasgow. "Data Handling in the Process Industries", by A. Parsons. **7.15 p.m.**

January 21. *South Wales Section:* At the Welsh College of Advanced Technology, Cardiff. "Data Logging", by C. H. Copley. **6.45 p.m.**

February 18. *Tees-side Section:* At the Cleveland Scientific and Technical Institute, Corporation Road, Middlesbrough. "Developing Reliability in New Machines: New Approach", by G. Morris. **7.30 p.m.**

The Institute of Physics

January 22-23. *At 47 Belgrave Square, London, S.W.1.* Symposium on "Nuclear Fuel Cycles".

The Institute of Petroleum

February 4. *At 61 New Cavendish Street, London, W.1.* "Chlorination of Salt Cooling Water at Coryton", by D. H. Tullis, A. T. Henderson and L. C. Neill. **5.30 p.m.**

The Institution of Civil Engineers

January 21. *At Great George Street, Westminster, London, S.W.1. Vernon-Harcourt Lecture:* "Hydraulic Models", by F. H. Allen. **6.30 p.m.**

February 10. At Great George Street, Westminster, London, S.W.1. "Automatic Analysis of Steel Framed Structures under Fixed and Varying Loads", by Jacques Heyman. **5.30 p.m.**

The Institution of Engineering Designers

January 29. *Yorkshire Branch:* At the Midland Hotel, Bradford. "Management and Productivity", by R. H. Harrison. **7.30 p.m.**

The Institute of Refrigeration

February 5. *At The Institute of Marine Engineers, The Memorial Building, 76 Mark Lane, London, E.C.3.* "Thermoelectric Cooling", by J. Goldsmid. **5.30 p.m.**

British Institute of Management

January 22. *At the Saville Room, Washington Hotel, Curzon Street, London, W.1.* One-day Seminar on Communication. **9.30 a.m.**

The Scientific Film Association

January 21. *At the Mezzanine Cinema, Shell-Mex House, Strand, London, W.C.2* "Films in the Service of Science", by Sir George Allen. **6.30 p.m.**

February 18. *At the Mezzanine Cinema, Shell-Mex House, Strand, London, W.C.2.* "Films in the Service of Industry—Some Observations by Industrial Film Users". **6.30 p.m.**